AIRCRAFT SERIOUS INCIDENT REPORT AND EXECUTIVE SUMMARY

			Reference:			CA18/3/2/1442	
Aircraft Registration	ZS-CMK		**Date of Incident**	26 March 2024		**Time of Incident**	0920Z
Type of Aircraft	Bombardier CL-600-2B19		**Type of Operation**			Commercial (Part 121)	
Pilot-in-command Licence Type	Airline Transport Licence (ATPL)		**Age**	64		**Licence Valid**	Yes
Pilot-in-command Flying Experience			**Total Flying Hours**	18 357		**Hours on Type**	624.1
Last Point of Departure	O.R. Tambo International Airport (FAOR), Gauteng Province						
Next Point of Intended Landing	George Airport (FAGG), Western Cape Province						
Damage to Aircraft	Substantial						
Location of the incident site with reference to easily defined geographical points (GPS readings if possible)							
En route to George Airport (FAGG) at FL300							
Meteorological Information	Wind direction: 150º; Wind speed: 07kts; Temperature: 22ºC; Dew Point: 15ºC; Cloud Cover: Few 030OVC 045; Cloud Base: 4 500ft; Visibility: CAVOK; QNH: 1015hPa						
Number of People On-board	2+1+48	**Number of People Injured**	0	**Number of People Killed**	0	**Other (On Ground)**	0

Synopsis

On Tuesday, 26 March 2024, a Bombardier CL-600-2B19 aircraft registered ZS-CMK with call sign KEM404 was on a scheduled commercial flight from O.R. Tambo International Airport (FAOR) in Gauteng province to George Airport (FAGG) in the Western Cape province. On-board the aircraft were two flight deck crew (pilots), one cabin crew and 48 passengers.

The aircraft departed from FAOR to FAGG at 0810Z, operated under instruments flight rules [IFR]. Around 0930Z whilst cruising at FL300 and about 10 minutes before the top of descent, the starboard (right-side) cockpit windshield cracked. The first officer (FO) who was the pilot flying (PF) promptly donned the oxygen mask and declared an emergency to Cape Town (FACT) air traffic control (ATC). The ATC officer cleared the aircraft to descend to FL090. The aircraft descended safely and, later, executed an uneventful landing on Runway (RWY) 11 at FAGG. The damage was confined to the starboard cockpit windshield; all occupants were not injured.

Upon inspection of the starboard windshield assembly, significant fractures were found on the outer glass layer; moreover, extensive delamination was found between the outer and intermediate layers on the heating element interface. This delamination caused the temperature gradient which increased stress on the glass. The primary cause of the failure was localised arcing where delamination had occurred; this was likely due to moisture ingress between the glass layers. The arcing increased localised stress which led to the windshield's crack.

Probable Cause/s and/or Contributory Factors			
Electrical arcing in the heating element, evidenced by the discoloured polymer interlayer, was a significant factor which caused the crack on the windshield. The arcing caused localised high temperatures and electrical stress. Extensive delamination between the outer glass layer and the interlayer on the heating element interface compromised the heating element's effectiveness. The temperature gradient and stress of the malfunctioning heating element likely caused the delamination. The stress which exceeded the tempered glass layer's limits led to the fracture and further delamination.			
SRP Date	12 November 2024	Publication Date	13 November 2024

Occurrence Details

Reference Number	**:** CA18/3/2/1442
Occurrence Category	**:** Category 1
Type of Operation	**:** Commercial Flight (Part 121)
Name of Operator	**:** CemAir (PTY) LTD
Aircraft Registration	**:** ZS-CMK
Aircraft Make and Model	**:** Bombardier Aerospace, CL-600-2B19
Nationality	**:** South Africa
Place	**:** En route to FAGG at FL300
Date and Time	**:** 26 March 2024; 0920Z
Injuries	**:** None
Damage	**:** Substantial

Purpose of the Investigation

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

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

Investigation Process

The Accident and Incident Investigations Division (AIID) was notified of the occurrence on 26 March 2024 at 0920Z. The occurrence was classified as a serious incident according to the CAR 2011 Part 12 and the International Civil Aviation Organisation (ICAO) STD Annex 13 definitions. The notifications were sent to the State of Registry, Operator, Design and Manufacturer in accordance with the CAR 2011 Part 12 and the ICAO Annex 13 Chapter 4. The State of Manufacturer appointed a non-traveling accredited representative and advisor. Investigators did not dispatch to the site for this serious incident.

Notes:

1. *Whenever the following words are mentioned in this report, they shall mean the following:*
   Serious Incident — this investigated serious incident
   Aircraft — the Bombardier CL-600-2B19 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

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Table of Contents

Abbreviation	Description
°	Degrees
°C	Degrees Celsius
a/c	Aircraft
AIID	Accident and Incident Investigations Division
AMO	Aircraft Maintenance Organisation
AMSL	Above Mean Sea Level
AOC	Air Operating Certificate
ATC	Air Traffic Control
ATPL	Airline Transport Pilot Licence
CAR	Civil Aviation Regulations
C of A	Certificate of Airworthiness
C of R	Certificate of Registration
CRM	Crew Resource Management
CRS	Certificate of Release to Service
CVR	Cockpit Voice Recorder
FAGG	George Airport
FAOR	O.R. Tambo International Airport
FCOM	Flight Crew Operations Manual
FDR	Flight Data Recorder
FL	Flight Level
ft	Feet
FO	First Officer
GPS	Global Positioning System
hPa	Hectopascal
ICAO	International Civil Aviation Organisation
IIC	Investigator-in-charge
ILS	Instrument Landing System
Km	Kilometre/s
Kt/s	Knot/s
m	Metres
METAR	Meteorological Routine Aerodrome Report
PF	Pilot Flying
PM	Pilot Monitoring
QNH	Query: Nautical Height
RWY	Runway
SACAA	South African Civil Aviation Authority
SAWS	South African Weather Service
SoE	Sequence of Events
TOD	Top of Descend
TTSN	Total Time Since New
UP	University of Pretoria
UTC	Co-ordinated Universal Time
UV	Ultraviolet
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
Z	Zulu (Term for Universal Co-ordinated Time - Zero Hours Greenwich)

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1. On Tuesday morning, 26 March 2024, a Bombardier CL-600-2B19 aircraft with registration ZS-CMK and operating under call sign KEM404 was on a scheduled commercial flight from O.R. Tambo International Airport (FAOR) in Gauteng province to George Airport (FAGG) in the Western Cape province. On-board the aircraft were two flight deck crew (pilots), one cabin crew and 48 passengers. Visual meteorological conditions (VMC) by day prevailed at the time of the flight which was conducted under the provisions of Part 121 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.1.2. The aircraft departed FAOR at 0810Z. There were no defects noted prior to departure. The first officer (FO) who was the pilot flying (PF) at the time of the serious incident stated that around 0920Z whilst cruising at flight level (FL) 300 and approximately 10 minutes before the top of descent (TOD), the starboard (right-side) cockpit glass windshield cracked (the windshield remained attached to the aircraft's fuselage). The FO promptly donned his oxygen mask. The FO stated that the crack occurred approximately 3 minutes after the captain had stepped out of the cockpit to use the restroom. The aircraft cabin did not depressurise, however, for safety purposes, the FO declared an emergency call to the Cape Town International Airport (FACT) air traffic control (ATC) on the very high frequency (VHF) 118.90 Megahertz (MHz). He then referenced the Quick Reference Handbook and descended to FL090 as outlined in the manual after obtaining approval from the ATC. When the captain returned to the cockpit as the aircraft was in descent, he also donned his oxygen mask.

1.1.3. The pilot commenced the instrument landing system (ILS) approach and landed safely on Runway (RWY) 11 at FAGG with no reported injuries to passengers and the crew. The aircraft sustained damage to the starboard cockpit windshield.

1.2. Injuries to Persons

Injuries	Pilot	Crew	Pass.	Total On-board	Other
Fatal	-	-	-	-	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	2	1	48	51	-
Total	**2**	**1**	**48**	**51**	**-**

Note: Other means people on the ground.

1.3. Damage to Aircraft

1.3.1. The starboard windshield cracked in-flight.


Figures 1 and 2: The cracked right-side windshield. (Source: Operator)

1.4. Other Damage

1.4.1. None.

1.5. Personnel Information

Captain (Pilot Monitoring)

Nationality	South African	Gender	Male	Age	64
Licence Type	Airline Transport Pilot Licence (ATPL) - Aeroplane				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument Rating				
Medical Expiry Date	30 March 2024				
Restrictions	Corrective lenses for defective near and distant vision				
Previous Incidents	None				

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

Flying Experience:

Total Hours	18 357
Total Past 24 Hours	7.7
Total Past 7 Days	17.1
Total Past 90 Days	197
Total on Type Past 90 Days	197
Total on Type	624.1

1.5.1. The captain was initially issued an Airline Transport Pilot Licence (ATPL) on 5 February 2003 under the provisions of Part 61 of the CAR 2011. The licence was revalidated on 23 January 2024 with an expiry date of 30 March 2025.

1.5.2. The captain was issued a Class 1 medical certificate on 29 September 2023 with an expiry date of 30 March 2024.

1.5.3. The captain was issued a refresher Crew Resource Management (CRM) Certificate on 12 March 2024 with an expiry date of 31 March 2025.

First Officer (Pilot Flying)

Nationality	South African	Gender	Male	Age	39
Licence Type	Airline Transport Pilot Licence (ATPL) - Aeroplane				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument Rating and Instructor Grade 2				
Medical Expiry Date	31 March 2024				
Restrictions	None				
Previous Incidents	None				

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

Flying Experience:

Total Hours	5 960
Total Past 24 Hours	4.7
Total Past 7 Days	20.3
Total Past 90 Days	100
Total on Type Past 90 Days	100
Total on Type	710

1.5.4. The first officer (FO) was initially issued an Airline Transport Pilot Licence (ATPL) on 3 February 2012 under the provisions of Part 61 of the CAR 2011. The licence was revalidated on 10 March 2023 with an expiry date of 31 March 2024.

1.5.5. The FO was issued a Class 1 medical certificate on 7 March 2023 with an expiry date of 31 March 2024.

1.5.6. The FO was issued a refresher Crew Resource Management Certificate on 23 November 2023 with an expiry date of 28 November 2024.

1.6. Aircraft Information

1.6.1. Aircraft Description (Source: www.skybrary.aero)

The Bombardier CL-600-2B19 aircraft is a regional jet designed and manufactured by Bombardier Aerospace in Canada. The aircraft has a service ceiling of 41 000ft and is powered by two General Electric (GE) CF34 turbofan engines mounted on the rear fuselage. The ZS-CMK had 50 seats installed in the cabin at the time of the serious incident flight.

Figure 3: The ZS-CMK aircraft. (Source: https://www.jetphotos.com)

Airframe:

Manufacturer/Model	Bombardier Inc / CL-600-2B19	
Serial Number	7292	
Year of Manufacture	1999	
Total Airframe Hours (At Time of Serious Incident)	31 468.46	
Last Inspection (Date & Hours)	9 March 2023	31 118.84
Airframe Hours Since Last Inspection	349.62	
CRS Issue Date	25 March 2024	
C of A (Issue Date & Expiry Date)	13 December 2023	12 December 2024
C of R (Issue Date) (Present Owner)	2 November 2023	
Operating Category	Standard Transport Category (Aeroplane)	
Type of Fuel Used	Jet A1	
Previous Incidents	None	

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

1.6.2. The aircraft was issued a Certificate of Release to Service (CRS) on 25 March 2023 with an expiry date of 9 March 2025 or at 31 571.91 airframe hours, whichever occurs first.

1.6.3. The ZS-CMK aircraft was imported from Sudan in December 2023. The Certificate of Airworthiness (C of A) was issued on 9 March 2022 with an expiry date of 30 November 2022.

1.6.4. The right-side windshield had not been replaced after the aircraft was imported to South Africa. The windshield is classified as an 'on-condition' item which means that it is not tracked as a life-limited or hard-time component. Therefore, the windshield is replaced based on its condition. The aircraft had been in South Africa for three months when the windshield defect occurred.

1.6.5. The window had accumulated 31 468.46 flying hours at the time of the serious incident and 349.62 flying hours since the last inspection.

Windshield and Side Window Anti-Ice System – Description and Operation (Source: CRJ 200 Aircraft Maintenance Manual)

The flight compartment windows let the crew see out of the flight compartment. They include the windows that follow:

– Two windshields

– Two side windows

The heater system for the windshields and side windows uses electrical power for the anti−icing and de−misting procedures. The windshields and side windows have electrical heater elements and temperature sensors built into their laminated glass construction. Overtemperature and a no−heat condition is detected by the sensors. If a no−heat condition occurs, the engine indication and crew alerting system (EICAS) is alerted. The system is monitored and controlled by four temperature controllers.

The controllers have an overtemperature circuit which is different from the normal HI or LOW control circuit. This circuit is a safety circuit that will isolate the heater from its power source at a set temperature level. The overtemperature circuit uses a temperature sensor that is identical to the sensor used in the normal control circuit. If there is a heater failure on a windshield or a side window, the MASTER CAUTION lights flash on the glareshield. A message is also shown on the primary display page of EICAS. The message is shown in the colour amber and will show the window heater that is defective. When the TEST switch on the anti−ice panel is pressed in, a 28−volt−dc signal will start a test procedure. This test will show that the temperature controllers, sensors, and heaters as a system are operational. The test circuits are as follows:

– The warm−up circuit is operational

– There are no failures in the normal control circuit

– The overheat protection circuit is operational

– The temperature sensors in the overheat protection circuits are not shorted.

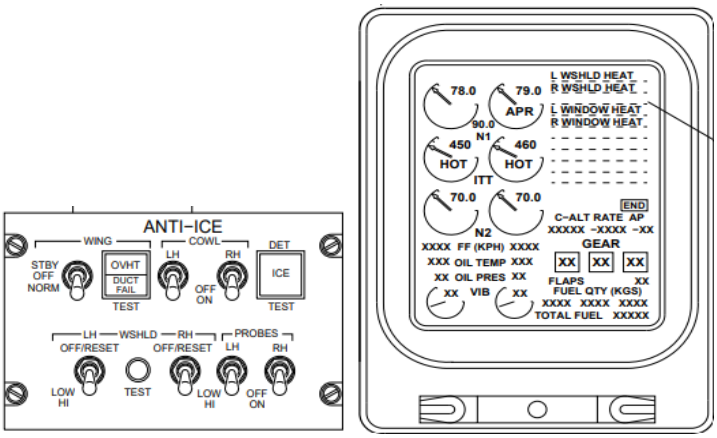
The test indications on the EICAS Display are caution messages as follows:

– L WINDOW HEAT

– L WSHLD HEAT

– R WINDOW HEAT

– R WSHLD HEAT.



Figures 4 and 5: The anti-ice panel and EICAS.

Engine #1:

Manufacturer/Model	General Electric Company / CF34
Serial Number	807466
Part Number	CF34-3B1
Hours Since New	30 112.39
Hours Since Overhaul	Not yet Reached

Engine #2:

Manufacturer/Model	General Electric Company / CF34
Serial Number	872683
Part Number	CF34-3B1
Hours Since New	35 805.89
Hours Since Overhaul	Not yet Reached

1.7. Meteorological Information

1.7.1 The weather information below was obtained from the pilot questionnaire (submitted by the captain) on 26 March 2024 at 0930Z.

Wind Direction	150°	Wind Speed	7kts	Visibility	9999m
Temperature	22°C	Cloud Cover	Few 030OVC 045	Cloud Base	4 500 ft
Dew Point	15°C	QNH	1015hPa		

1.8. Aids to Navigation

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

1.9. Communication

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

1.9.2. The crew was communicating with FACT ATC on frequency 118.90MHz.

1.10. Aerodrome Information

Aerodrome Name	George Airport (FAGG)
Aerodrome Location	George, Western Cape Province
Aerodrome Status	Licensed
Aerodrome GPS coordinates	34°00′24″ South, 22°22′51″ East
Aerodrome Elevation	639 ft AMSL
Runway Headings	02 /20 and 11/ 29
Dimensions of Runway Used	1 158x 30 m and 2 000 x 45 m
Heading of Runway Used	11
Surface of Runway Used	Asphalt
Approach Facilities	ILS, VOR, Localiser, NDB, GPS/GNSS
Radio Frequency	118.90 (Tower)

1.11. Flight Recorders

1.11.1. The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR) as required by regulation.

1.12. Wreckage and Impact Information

1.12.1. None.

1.13. Medical and Pathological Information

1.13.1. None.

1.14. Fire

1.14.1. There was no pre- or post-impact fire.

1.15. Survival Aspects

1.15.1. The serious incident was considered survivable. The cabin remained pressurised during descent.

1.16. Tests and Research

1.16.1. The cracked starboard (co-pilot) cockpit windshield (Photo 1), PPG Part No FAA PMA NP139322- 12, Serial No 08303H7346 from a Bombardier CRJ100-ER, aircraft registration

ZS-CMK (Figure 1), Serial No 7273 was sent to the University of Pretoria (UP) laboratory to determine:

(a) The fracture mode
(b) The probable cause/s thereto
(c) The most probable failure sequence of events (SoE)

Figure 6: Cracked windshield.

1.16.2. Visual Inspection Results: Starboard Windshield Assembly

The visual inspection revealed multiple fractures originating from the bottom right-side area (pilot's view) and extending in two directions (Photos 1 and 2, red circle, red arrows). Extensive delamination was noted between the outer glass layer (Diagram 1) and the interlayer at the anti-icing heating element interface (Photos 2 and 3, blue demarcation). This will be detrimental to the effectiveness of the heating element while in operation, resulting in a temperature gradient between the outer and the inner sections of the glass layer inducing (applied) stresses. Selected areas revealed indications of recent delamination (Photo 3, blue dashed lines) most probably induced following the initial failure of the outer glass layer. At the point of initiation, clear indications of discolouring of the polymer interlayer were noted suggesting electrical arcing involving the heating element (Photo 3, yellow circle). The initial fracture originated from the delaminated zone and at the point of arcing. The arcing would have further increased the temperature gradient within a small area resulting in increased stresses exceeding the designed limits (compression/tension region) of the Tempered Glass layer. Inspection of the windshield seals and outer frame revealed no clear indication/s of excessive wear and/or incorrect fitting (Photo 4).

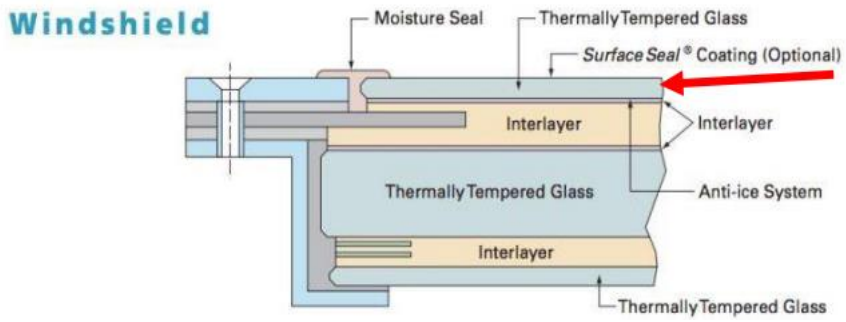


Diagram 1: Schematic: Generic windshield construction.

Photo 1: Inside view (digital).

Photo 2: Outside view (digital).

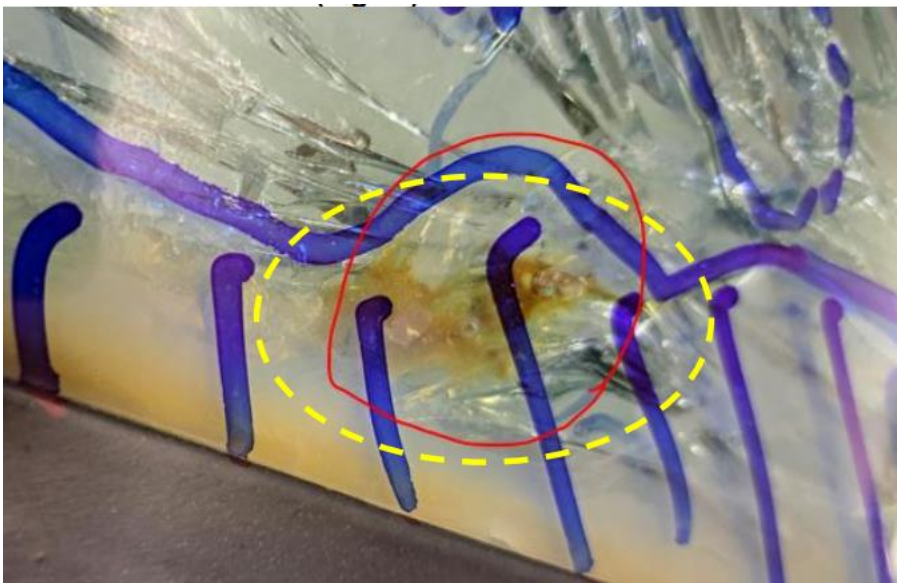


Photo 3: Arcing indications (digital).

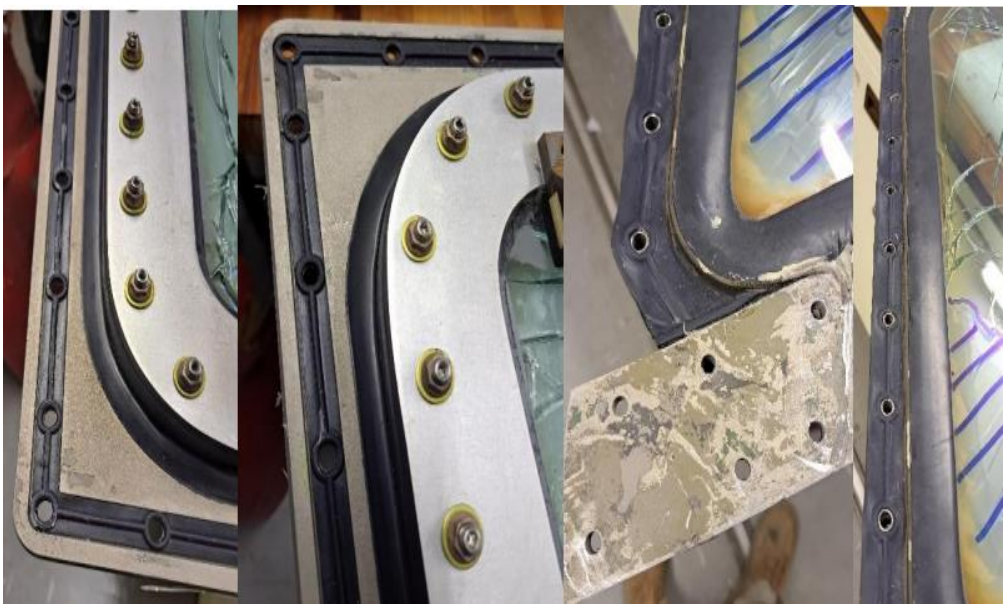


Photo 4: Windshield seal condition (digital).

CONCLUSIONS

(a) The inspection of the starboard windshield assembly revealed multiple (large shards) fractures within the outer, thermally tempered glass layer.

(b) The windshield revealed extensive circumferential delamination between the outer and intermediate layers at the heating element interface. This contributed to a temperature gradient between the outer and inner zones of the glass layer, increasing the applied stresses during operation. Delamination proved to be the most common cause of failure of heated windshield assemblies.

(c) The fracture initiated within the delaminated zone at a point where the heating element revealed signs of localised arcing. The increased localised stresses are most probably the primary causational factor towards the initiation of the final failure. The arcing can be

attributed to moisture ingestion between the outer glass and the intermediate polymer layer delaminated areas during operation.

Sequence of Events:

The following are the most probable sequence of events:

(a) Delamination of the windshield assembly due to time exposure (UV, moisture, etc.). This would increase the applied stresses within the outer glass layer during operation.

(b) Ingestion of moisture within the delaminated zones.

(c) Arcing of the heating element due to the increased moisture content.

(d) Localised stresses resulted in the initiation of the primary fracture. The already present stresses induced by the general delamination and the applied stress by cabin pressurisation supported fracture progression.

1.17. Organisational and Management Information

1.17.1. This was a commercial flight operated under the provisions of Part 121 of the CAR 2011 as amended.

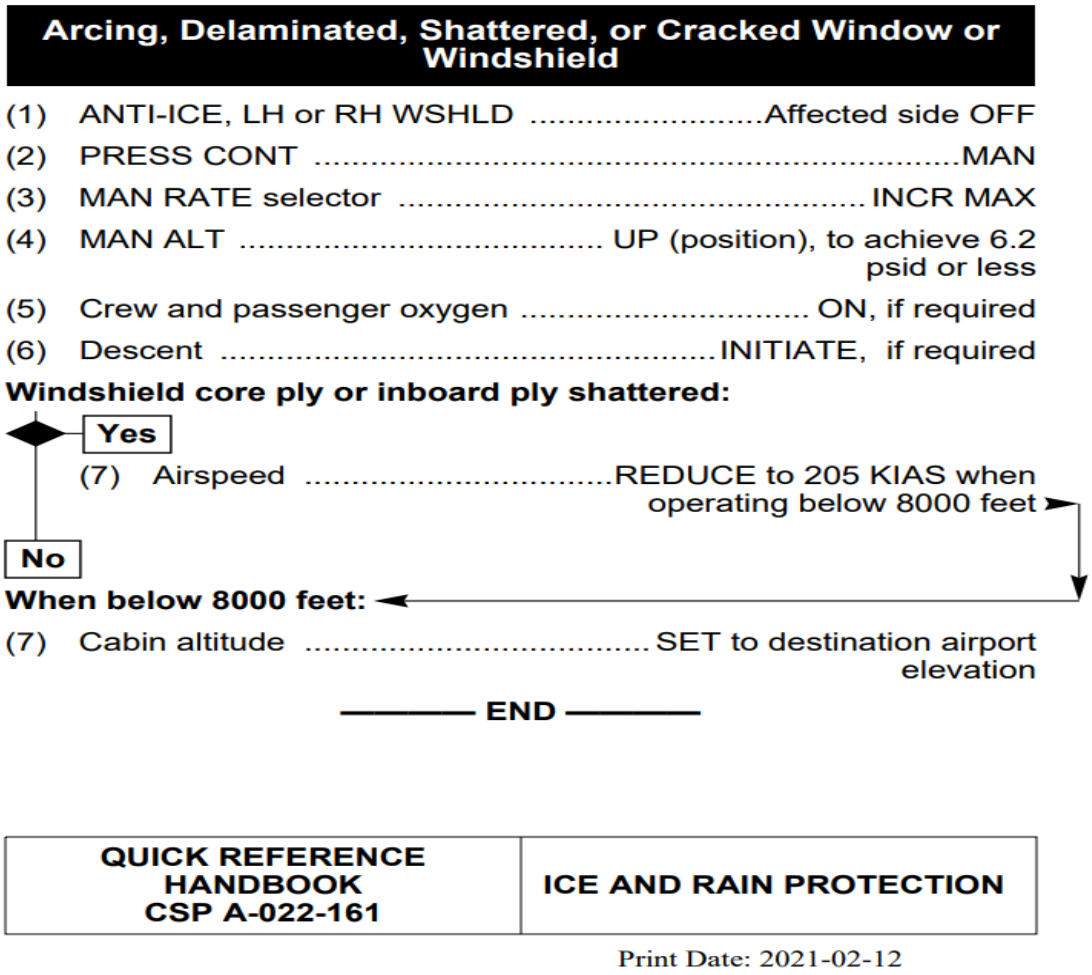
1.17.2. The operator had an Aircraft Operating Certificate (AOC) that was issued by the SACAA on 13 November 2023 with an expiry date of 30 November 2024.

1.17.3. The aircraft was maintained by the SACAA-approved aircraft maintenance organisation (AMO). The AMO was issued an AMO Certificate on 2 March 2023 with an expiry date of 31 March 2024.

1.18. Additional Information

1.18.1. According to the Bombardier CL-600-2B19 QRH, the 'Arcing, Delaminated, Shattered, or Cracked Window or Windshield' checklist should be conducted if arcing, delamination, shattering, or cracking of a window or windshield occurs.

1.18.2. The following information is extracted from the Bombardier CL-600-2B19 Flight Crew Operations Manual (FCOM). The extract reflects the procedures and guidelines that were adhered to by the flight crew in accordance with the aircraft’s operational procedures. The FCOM provides detailed instructions and checklists designed to ensure safe and effective handling of various in-flight scenarios, and the crew followed these specific procedures as outlined in the manual:



Arcing, Delaminated, Shattered, or Cracked Window or Windshield

(1) ANTI-ICE, LH or RH WSHLD .....Affected side OFF
(2) PRESS CONT .....MAN
(3) MAN RATE selector ..... INCR MAX
(4) MAN ALT ..... UP (position), to achieve 6.2 psid or less
(5) Crew and passenger oxygen ..... ON, if required
(6) Descent .....INITIATE, if required

Windshield core ply or inboard ply shattered:

Yes

(7) Airspeed .....REDUCE to 205 KIAS when operating below 8000 feet

No

When below 8000 feet:

(7) Cabin altitude ..... SET to destination airport elevation

END

QUICK REFERENCE HANDBOOK CSP A-022-161	ICE AND RAIN PROTECTION

Print Date: 2021-02-12

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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 serious incident. This shall not be read as apportioning blame or liability to any organisation or individual.

2.2. Analysis

Man

2.2.1. The crew's licenses and medical certificates were valid, and the crew met all regulatory requirements for operating the aircraft, including type endorsement and medical fitness. The FO responded promptly when the windshield cracked, consulted the Quick Reference Handbook, and descended to FL090 as outlined in the manual.

Mission

2.2.2. This was a commercial passenger flight conducted under the provisions of Part 121 of the CAR 2011 as amended.

Machine (Aircraft)

2.2.3. The aircraft had been in South Africa for three months when the windshield defect occurred. The C of A had expired on 30 November 2022. The aircraft was first registered to the present owner on 2 November 2023. The inspection and CRS were recent and in compliance with the regulations.

The aircraft's windshield on the starboard cockpit cracked whilst the aircraft was cruising at FL300; the windshield remained securely attached to the aircraft's fuselage after the crack. The windshield had accumulated 31 468.46 flying hours at the time of the serious incident and had 349.62 flying hours since the last inspection. The windshield is an on-condition item.

The anti-icing panel is checked through a "TEST" button to determine the serviceability of the window heating during "pre-flight checks"; however, the test did not pick up any defects. If a heater fails on a windshield or a side window, the MASTER CAUTION lights flash on the glareshield. A message is also shown on the primary display page of EICAS. The message is shown in an amber colour and will show the defective window heater. However, it did not show the warning and message before the failure of the window.

The inspection of the starboard windshield assembly showed significant fractures in the outer glass layer and extensive delamination between the outer and intermediate layers on the heating element interface. This delamination caused temperature gradient that increased stress on the glass. The primary cause of the failure was localised arcing at a point where delamination had occurred, likely due to moisture ingress between the glass layers. The arcing increased localised stress which led to the windshield's crack.

Weather

2.2.4. Fine weather conditions prevailed at the time of the flight; the weather had no bearing on this serious incident.

3. CONCLUSION

3.1. General

From the available evidence, the following findings, causes and contributing factors were made with respect to this serious 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 serious 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 serious 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 captain was initially issued an Airline Transport Pilot Licence (ATPL) on 5 February 2003 under the provisions of Part 61 of the CAR 2011. The licence was revalidated on 23 January 2024 with an expiry date of 30 March 2025.

3.2.2. The captain was issued a Class 1 medical certificate on 29 September 2023 with an expiry date of 30 March 2024.

3.2.3. The captain was issued a refresher Crew Resource Management (CRM) Certificate on 12 March 2024 with an expiry date of 31 March 2025.

3.2.4. The first officer (FO) was initially issued an Airline Transport Pilot Licence (ATPL) on 3 February 2012 under the provisions of Part 61 of the CAR 2011. The licence was revalidated on 10 March 2023 with an expiry date of 31 March 2024. The FO had the Instrument and Instructor Grade 2 ratings in accordance with (IAW) the existing regulations.

3.2.5. The FO was issued a Class 1 aviation medical certificate on 7 March 2023 with an expiry date of 31 March 2024.

3.2.6. The FO was issued a refresher Crew Resource Management Certificate on 23 November 2023 with an expiry date of 28 November 2024.

3.2.7. The aircraft was issued a Certificate of Registration (C of R) on 2 November 2023.

3.2.8. The aircraft was hangared and grounded in Sudan between November 2022 and December 2023. It was imported to South Africa with an expired C of A which was issued on 9 March 2022 with an expiry date of 30 November 2022. The windshield defect occurred three months after the aircraft was imported to South Africa. The aircraft was reissued a Certificate of Airworthiness (C of A) in South Africa on 13 December 2023 with an expiry date of 12 December 2024.

3.2.9. The last mandatory periodic inspection (MPI) that was conducted on the aircraft prior to the serious incident flight was certified on 9 March 2023 at 31 118.84 airframe hours. The serious incident occurred at 31 468.46 total airframe hours, which meant that the aircraft accrued 349.62 hours since the last MPI inspection.

3.2.10. The aircraft was issued a Certificate of Release to Service (CRS) on 25 March 2023 with an expiry date of 9 March 2025 or at 31 571.91 airframe hours, whichever occurs first.

3.2.11. The operator had an Aircraft Operating Certificate (AOC) that was issued by the Regulator on 13 November 2023 with an expiry date of 30 November 2024.

3.2.12. The AMO which conducted the last MPI on the aircraft had an AMO Certificate that was issued on 2 March 2023 with an expiry date of 31 March 2024.

3.2.13. The window had accumulated 31 468.46 flying hours at the time of the serious incident, and it had been flown for 349.62 flying hours since the last inspection.

3.2.14. The anti-icing panel had a “TEST” button for “pre-flight checks” and a message would display on EICAS if there was a window failure.

3.2.15. The aircraft’s windshield of the starboard cockpit cracked whilst cruising at FL300, but the window remained securely attached to the aircraft’s fuselage.

3.2.16. The primary cause of the crack was localised arcing at a point where delamination had occurred, likely due to moisture ingress between the glass layers.

3.3. Probable Cause

3.3.1. Electrical arcing in the heating element, evidenced by the discoloured polymer interlayer, was a significant factor in the windshield failure. This arcing caused localised high temperatures and electrical stress. Extensive delamination between the outer glass layer and the interlayer on the heating element interface compromised the heating element’s effectiveness. The temperature gradient and stress from the malfunctioning heating element likely caused the delamination. The stress exceeded the tempered glass layer’s limits, which led to the fracture and further delamination.

3.4. Contributory Factors

3.4.1. Delamination of the windshield assembly: Prolonged exposure to ultraviolet (UV) rays, moisture and other environmental factors can cause the windshield assembly to delaminate. This delamination increases the stress on the outer glass layer, which can compromise its integrity.

3.4.2. Ingestion of moisture: The delaminated zones allow moisture to enter and could affect the performance and safety of the windshield.

3.4.3. Arcing of the heating element: The increased moisture content within the delaminated zones could lead to electrical arcing in the heating element, potentially causing malfunctions or damage.

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 Recommendations

4.2.1. Regular inspection and maintenance: Implement routine inspections of the windshield heating elements to identify signs of electrical arcing or other malfunctions early. Pay particular attention to discoloured polymer interlayers and other indicators of potential issues.

4.2.2. Enhanced quality control: Ensure strict quality control measures are in place for the installation and maintenance of heating elements to prevent temperature gradients and stress that could lead to delamination.

4.2.3. Monitoring heating elements: Ensure that heating elements are inspected regularly for signs of arcing or damage. Address any issues promptly to prevent potential hazards associated with increased moisture content.

4.2.4. Training and awareness: Train maintenance personnel to recognise and address issues related to electrical arcing and delamination in windshield assemblies.

5. APPENDICES

5.1. None.

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