الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Serious Incident

- Final Summary Report -

AAIS Case Nº AIFN/0004/2021

Smoke/Fire from Windshield Window

Operator:	Cargolux Airlines
Make and Model:	Boeing 747-8RF
Nationality and Registration:	Luxumberg, LX-VCD
Place of Occurrence:	Al Maktoum International Airport, Dubai
State of Occurrence:	The United Arab Emirates
Date of Occurrence:	22 March 2021

This Investigation was conducted by the Air Accident Investigation Sector of the United Arab Emirates pursuant to Civil Aviation Law No. 20 of 1991, in compliance with Air Accident and Incident Investigation Regulations, and in conformance with the provisions of Annex 13 to the Convention on International Civil Aviation.

This Investigation was conducted independently and without prejudice. The sole objective of the investigation is to prevent future aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

The Air Accident Investigation Sector issued this Summary Report in accordance with national and international standards and best practice. Consultation with applicable stakeholders, and consideration of their comments, took place prior to the publication of this Report.

The Summary Report is publicly available at:

http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx

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Investigation Process

The flight deck windshield window smoke/ electrical sparks occurrence involved a Boeing 747-8RF Aircraft, registration marks LX-VCD owned by Cargolux Airlines. The occurrence was reported to the Air Accident Investigation Sector (AAIS) Duty Investigator by phone call to the Hotline Number +971 50 641 4667.

After the initial investigation at the site and assessment of the data, the occurrence was classified as a 'serious incident'.

The scope of this Investigation is limited to the events leading up to the occurrence; no in-depth analysis of non-contributing factors was undertaken.

Notes:

1. Whenever the following words are mentioned in this Report with a first capital letter, they shall mean the following:
   - (Aircraft) – the aircraft involved in this serious incident
   - (Commander) – the commander of the incident flight
   - (Copilot) – the copilot of the incident flight
   - (Incident) – the investigation into this serious incident
   - (Investigation) – the investigation into this serious incident
   - (Operator) – Cargolux Airlines
   - (Report) – this serious incident investigation Summary Report.
2. Unless otherwise mentioned, all times in the Report are 24-hour clock in Coordinated Universal Time (UTC), (UAE local time minus 4 hours).
3. The structure of this Summary Report is an adaptation of the ICAO Annex 13 Final Report format.

Factual Information

History of the Flight

On 22 March 2021, at 0122 UTC (0522 local time), a Boeing 747-8F Aircraft, registration marks LX-VCD, operated by Cargolux Airlines, departed from Al Maktoum International Airport (OMDW[1]) to Luxembourg International Airport (ELLX). There were six people on board, comprising two flight crewmembers and four deadhead[2] crew (two pilots and two aircraft maintenance engineers).

The Commander was the pilot monitoring (PM) and the Copilot was the pilot flying (PF).

At 0122:12, the Aircraft commenced a take-off roll from runway 30 and lifted off after 36 seconds.

At 0147:15, after levelling off at flight level (FL)280 the flight crew called the Bahrain ATC controller declaring PAN PAN due to a technical malfunction of the window heating system and requested to return to OMDW. The controller confirmed the request and provided instructions as required to the flight crew.

At 0148:00, the flight crew informed the controller about their intention to initiate fuel jettisoning[3]. The controller vectored the flight towards Dubai and queried for more details about the technical malfunction. The flight crew reported that there were electrical sparks followed by smoke from the right window windshield heating terminal block. The Commander, as the PM, switched off the right window heater electrical and the electrical sparks stopped and smoke dissipated from the cockpit.

The controller asked if any assistance is required at the arrival airport and the crew replied the sparks had stopped and smoke disseminated and there is no further assistance is needed at the arrival airport.

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1 OMDW is the ICAO four letter airport code for Al Maktoum International Airport, United Arab Emirates

2 A deadhead pilot is simply a pilot that's flying on a plane as a passenger on their way to or from an assigned route.

Source: https://www.skytough.com/post/what-is-a-deadhead-pilot

3 Fuel Jettison, more commonly referred to as Fuel Dumping, is the intentional, controlled, jettison of fuel from an aircraft whilst in flight.

Source: https://skybrary.aero/articles/fuel-dumping-guidance-flight-crews

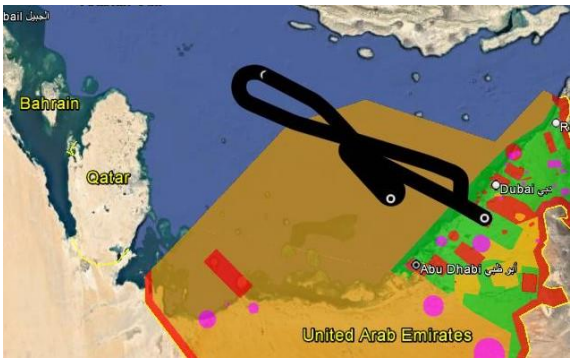

Figure 1. CX7957 flight path indicating UAE airspace

At 0150:00, the Aircraft started the descent. At 0152:52, the flight crew requested to begin the fuel jettisoning and the controller approved. The controller then instructed the crew to contact the area control center at frequency 132.15 MHz.

After the fuel jettisoning, the Aircraft landed at OMDW at 0242:52 uneventfully. The Commander informed the Tower controller that no assistance is required. However, the controller declared a full emergency prior to the Aircraft landing.

After landing, the runway and the taxiway were inspected for any foreign objects or debris and nothing was found. Thereafter the fire commander cancelled the emergency at 0252:00.

Damage to Aircraft and Property

There was no damage to the Aircraft or property.

Personnel Information

The Commander held an air transport pilot license (ATPL) issued by the Directorate of Civil Aviation of Luxembourg with validity until 30 November 2021. His medical certificate was valid until 5 October 2021

The Copilot held an ATPL issued by DAC with validity until 30 October 2021. His medical certificate was valid until 15 February 2022. Based on the training records, both flight crewmembers were current. They also stated that they were well-rested and fit for the flight.

Aircraft Information

General data

The Aircraft was manufactured in October 2011 and was issued the first certificate of airworthiness on 13 Oct 2011 and the last renewal was on 30 Sep 2021 to be valid until 13 Oct 2022.

The time since the last C-check was 2,789 flight hours, 490 cycles. The last A-check was accomplished in February 2021.

The maximum take-off, landing, and zero fuel weights were 447,695, 346,090, and 329,761 kilograms, respectively.

Technical records

The windshield heating electrical terminal was damaged due to overheating causing electrical sparks.

The Aircraft flight technical logs provided to the Investigation showed no technical defects prior to the Incident.

There were no pending maintenance messages or maintenance fault messages reported post-completion of the flight.

As per the design, the FDR parameters did not include the window anti-icing heater's electrical power switch position.

Meteorological Information

The weather was normal.

Communications

ATC recordings obtained from Bahrain ATC were available and provided for the Investigation.

The Bahrain ATC recording was clear, and it revealed that the flight crew declared PAN PAN and informed ATC that they had a technical malfunction on the right window electrical terminal.

Flight Recorders

The Aircraft was fitted with L-3 Communications flight data recorder (FDR) and cockpit voice recorder (CVR). Both recorders were shipped to Abu Dhabi Flight Recorders Laboratory for download and analysis. The CVR was downloaded in Abu Dhabi Flight Recorders Laboratory. However, it was found overwritten and overwritten by the maintenance personnel conversations during the Aircraft inspection.

Tests and Research

Windshield Window Teardown and Testing

The right (R1) flight deck window was removed from the Aircraft and shipped to the Equipment Quality Analysis (EQA) Laboratory at the Boeing facility, in Seattle, United States. The initial inspection revealed the following general data:

- Part name: Copilot (R1) Windshield

- Boeing part number: 141U4800-24
- Supplier: GKN Aerospace Transparency Systems
- Supplier part number: 13933
- Serial number: G9025.

The windshield heat electrical terminals were photo-documented and removed from the windshield assembly. X-ray examinations were performed on the terminal assemblies. Electrical resistance checks were performed on the window heat components. All images and results of the examinations were provided to the Investigation.

Windshield Examination

Examination of the R1 windshield was conducted on 13 and 14 May 2021 with Boeing Air Safety Investigation (ASI) and Design Engineer (DE). The examination was hosted on live video conferencing with remote attendees from the National Transportation Safety Board of the United States (NTSB), AAIS, and the supplier.

The windshield terminal references are shown in figure 2 which refers to the *component maintenance manual (CMM)*.

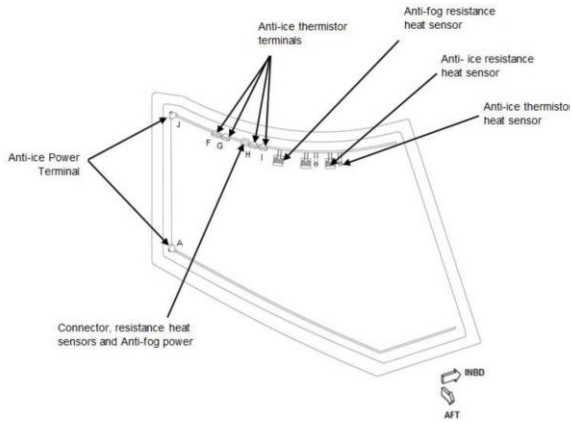

Figure 2. Windshield terminal locations - Left windshield

The windshield was removed from the shipment box and placed face down on the examination table. The windshield anti-ice power terminals (A) and (J) are identified in figure 3 below.

Figure 3. R1 Windshield s/n G9025 inside view and data tag

While conducting the physical examination, there were no defects noted with the sense elements and connections as shown in figure 4 below. There was no electrical testing performed at this time.

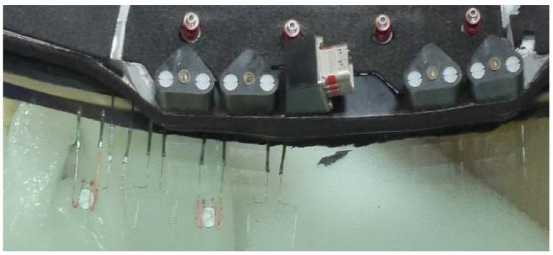

Figure 4. R1 Windshield s/n G9025 sense elements and connections

Windshield anti-ice electrical terminals (A) and (J) are shown in figures 5 and 6 below. Terminal (A) is anti-ice power IN and terminal (J) is anti-ice power OUT.

Figure 5. Windshield anti-ice terminal (J)

Figure 6. Windshield anti-ice terminal (A)

Evidence of heat damage was noted adjacent to the terminal (A) and deposited materials were noted on the transparency adjacent to (A). There were no defects noted on the terminal (J).

Evidence of discoloration due to heat was noted on the wire and case of the terminal (A) as shown in figures 7 and 8.

Figure 7. Windshield anti-ice terminal (A)

Figure 8. Windshield anti-ice terminal (A)

A hole was noted on the side of the terminal with evidence of heat damage. The windshield anti-ice terminals (A) and (J) were removed from the windshield assembly.

The X-ray digital radiography (DR) examinations were performed on windshield terminal (J) and (A) block assemblies as shown in figures 9 and 10. Parts inside the terminal (J) are the power braid wire, connector pin and retaining pin.

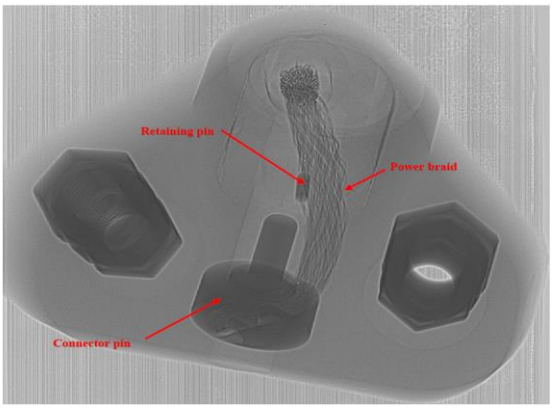

Figure 9. DR image of the terminal (J)

The part in the image of the terminal (A) shown in figure 10 are the power braid wire, connector pin, ship side wire and socket

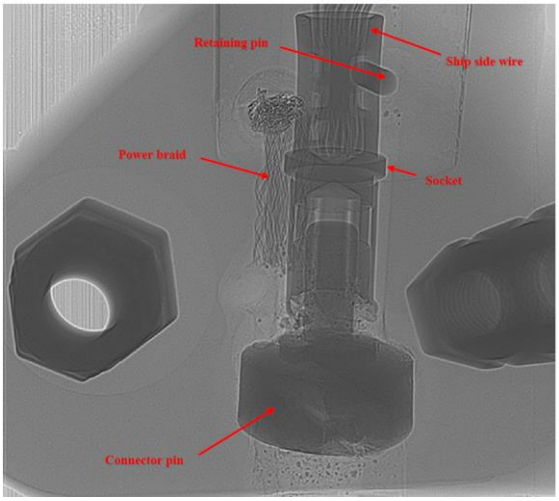

Figure 10. DR image of the terminal (A)

In addition to the X-ray digital radiography, X-ray computed tomography (CT) scans were performed on the terminal block assemblies prior to further disassembly.

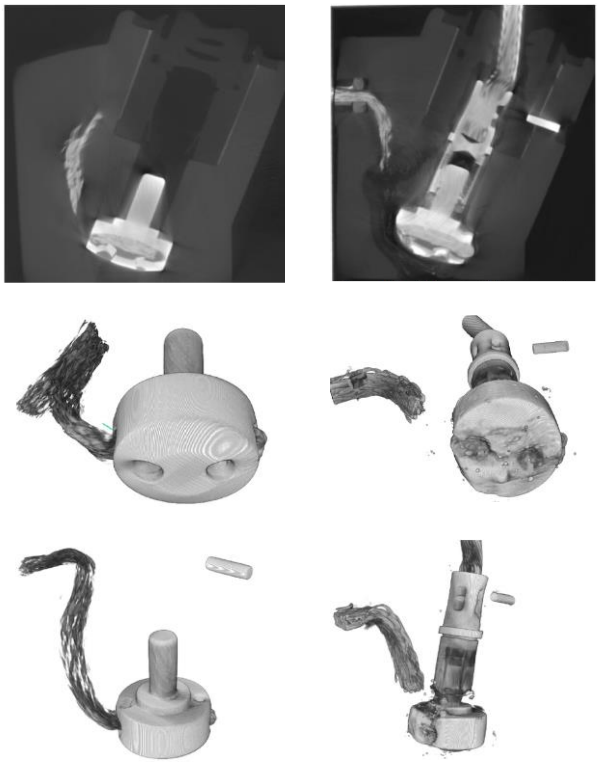

Figure 11. Terminal (J) CT cross-section

Figure 12. terminal (A) CT cross-section

Further CT scans were conducted on the terminal (J) as the power braid wire was intact and was not faulty as shown in figures 13, 14 and 15 below.

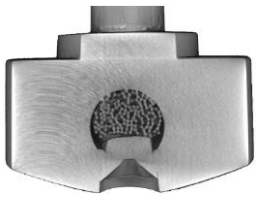

Figure 13. terminal (J) CT scan

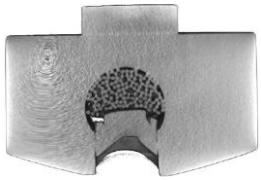

Figure 14. terminal (J) CT scan

Figure 15. Terminal (J) power braid wire crimped

Boeing-EQA testing results were delivered to all the involved stakeholders.

Window Heating Control Unit (WHCU) Examination

The WHCU was forwarded for functional tests from the Boeing facility to the manufacturer, Safran FCS in France.

As per the examination report, the physical examination of the WHCU did not reveal any scratches, dents, traces of impact or smoke or fire traces. The seals were present and the box had not been opened by a third party previously. The electrical connector pins were in good condition, with no traces of overheating or arcing on any of the pins. figure 16 illustrates the actual WHCU removed from the Aircraft.

Figure 16. Window heating control unit

The Aircraft documented records reveal that the unit had cumulated 3,450 days on the wing, 49,025 flight hours and 8,990 cycles at the moment of removal, which is consistent with its manufacture date (January 2011). As per the examination report, the WHCU was opened for the first time since it was installed on the Aircraft.

The acceptance test was carried out as per *CMM 30-41-17*. All the steps in the test sequence passed successfully and non-volatile memory was read and did not find any fault log.

The WHCU case was opened for a visual inspection of the electronic boards inside.

The three electronic boards did not reveal any overheating and the solder joints on the component were in good condition.

In conclusion following a successful functional test and detailed inspection of the WHCU and its assemblies show no anomaly in its aspect or functionalities.

Organizational and Management Information

Cargolux Airlines

The Operator was granted an air operator certificate (AOC) issued by the Directorate of Civil Aviation of Luxembourg and commenced operations in March 1970.

The airline provides freight services with a fleet of 30 aeroplanes, Boeing 747-8F (14), Boeing 747-400F (10) and Boeing 747-400 ERF (6).

Additional Information

On 16 January 2019, a Cargolux Boeing 747-8F aircraft with registration LX-VCJ operating flight number CX7303 from Kuala Lumpur, Malaysia, to Zhengzhou (China) was climbing at FL160, and the flight crew reported to ATC for having smoke and fire at the copilot side R1 windows heater electrical terminal. The aircraft returned to Kuala Lumpur and landed safely.

The internal investigation conducted by the operator in coordination with Boeing concluded that the probable cause of the smoke and fire was heat capability and concomitant electrical damage to the power connector of the windshield anti-ice heater that was precipitated by insufficient electrical conductivity within this terminal.

Arcing damage originated from where the integrated power wire joined the connector pin base. It appears that the fracture of wire strands at a

crimp point within the pin base caused the loss of current carrying capacity.

Conclusion of the joint investigation report and Corrective Actions

Faulty components within the right windshield anti-ice heater system triggered arcing, smoke and flames on the flight deck as observed and reported by the flight crew; they couldn't determine the cause at the time.

Boeing has taken over further investigation through their internal Continued Operation Safety Process to help prevent the recurrence of the issue. Cargolux also conducted a fleet-wide campaign immediately after the event to search for any loose wires or connections associated with the anti-ice windshield heater with nil findings.

Historical Data of windshield window terminal issues

On 21 January 2004, the Danish Aircraft Investigation Board notified the NTSB reporting an electrical fire started near the windshield heat terminal on an Air Greenland aircraft Boeing 757-200 with registration OY-GRL.

On 25 January 2004, American Airlines flight 1477, a 757-200 aeroplane, from Dallas (DFW) declared an emergency because of smoke and fire near the windshield heat terminal.

Both incident aircraft windshields were removed and shipped to the windshield manufacturer (PPG Inc). The teardown examination revealed that the cause of the fire was cross-threading[4] of the screw that attached the power wire to the windshield heat terminal block, which resulted in an electrical arc and fire.

During the above two incident investigations, Boeing reported to the NTSB and the Federal Aviation Administration of the United States (FAA) that there were similar four incidents involving Boeing 747,757,767 and 777 resulting in re-designing the terminal block. The FAA informed the NTSB of the intention to issue airworthiness directives(AD).

Boeing issued a service bulletin (SB) for B777 aircraft on 7 April 2004, however, SBs for B747, B757 and B767 were still pending at that time. Subsequently, three more incidents involving 757 aircraft occurred before Boeing issued the SBs.

On 2 May 2004, American Airlines Boeing 757-200 operating flight 2107 from Miami to Caracas, Venezuela, suffered fire near the windshield heat terminal.

On 23 February 2006, the NTSB received an Aviation Safety Reporting System (ASRS) from the National Aeronautics and Space Administration (NASA) about smoke and fire near the windshield heat terminal of a B757 from an unknown operator.

On 23 April 2006 American Airlines flight 923, a Boeing 757-200, diverted to John F. Kennedy International Airport because of smoke in the cockpit. The post-landing maintenance inspection revealed that an electrical short in the windshield heat terminal block occurred due to a cross-threaded screw.

The FAA informed the NTSB about the intention to issue an AD to require an inspection of the flight deck windshields to look for a cross-thread condition and to require corrective action as per the Boeing SB, installation of a new windshield with the new style terminal block.

The NTSB issued two safety recommendations (*A-07-49 and A-07-50*) to FAA in 2007 stating:

- *A-07-49.* Complete the process that began to approve the service bulletin for installation of the redesigned heat terminal block on Boeing 767 aircraft.
- *A-07-50.* Issue airworthiness directives to replace the windshield heat terminal block on all Boeing 747, 757, 767 and 777 aircraft with the Boeing service bulletins.

FAA airworthiness directives (ADs)

On 12 July 2012, the FAA issued 14 CFR Part 39, Docket No. FAA-2010-1115; Directorate Identifier 2010-NM-221-AD, Amendment 39-17111; AD 2012-13-09.

This AD was addressed to the Boeing models 747-100, 747-100B, 747-100B SUD, 747-200B, 747-200C, 747-300, 747-400, 747-400D, 747-400F, 747SR and 747SP. Boeing released a service bulletin (SB) 747-30-2081 in August 2006 (currently Rev. 5, released in January 2017) to address windshield inspections and replacement

[4] A cross-thread condition is created when the screw is installed in the terminal block such that the screw's axis and the terminal's axis are misaligned. Because of the torque created by the misaligment the screw cannot be fully seated in the thermal which results in a loose electrical connection between the wire and the terminal block.

[Source: NTSB safety recommendation A-7-40 and 50]

with a pin/socket electrical terminal design. The 747-8 model was not included in the associated AD or SB because it incorporated a pin/socket terminal design in production prior to service.

"We are adopting a new airworthiness directive (AD) for certain The Boeing Company Model 747-100, 747-100B, 747-100B SUD, 747-200B, 747-200C, 747-200F, 747-300, 747-400,747-400D, 747-400F, 747SR, and 747SP series airplanes. This AD was prompted by several reports of electrical arcs at terminal "A" of the electrically heated flight deck window 1. This AD requires repetitive inspections for damage of the electrical connections at terminal "A" of the left and right flight deck window 1, and corrective actions if necessary. This AD also allows for replacing a flight deck window 1 with a new improved flight deck window 1 equipped with different electrical connections, which would terminate the repetitive inspections for that window. We are issuing this AD to prevent smoke and fire in the cockpit, which could lead to loss of visibility, and injuries to or incapacitation of the flight crew."

This AD allows replacing an affected windshield with a windshield equipped with different electrical connections, which would terminate the repetitive inspections for that windshield. This AD was effective on 16 August 2012.

Boeing Service Bulletin (SB)

SB 747-30-2081 was originally issued on 8 August 2006, and revision 5 was issued on 10 January 2017. The subject was "Subject: Ice And Rain Protection – Flight Compartment Window Anti-Icing System – Windshield Inspection and Replacement." The SB revision history was as shown in table 1.

Table 1. SB 747-30-2018 revision history

Original Issue:	8 August 2006
Revision 1	20 August 2008
Revision 2	10 March 2010
Revision 3	5 December 2011
Revision 4	6 March 2014
Revision 5	10 January 2017

Analysis

Pilot Qualification and Aircraft Airworthiness

Both pilots were qualified and current for the flight as per the regulatory requirements.

There was neither evidence of any reported defects by the flight crew related to the serviceability of onboard navigation aids, nor evidence of any systems' malfunction of the Aircraft during flight except the windshield terminal smoke and fire.

The Aircraft records indicated that it was airworthy when dispatched for the flight. Hence, the Investigation concluded that the Aircraft was airworthy when dispatched for the flight.

The environmental conditions were also normal and it is not a contributory factor to the Incident.

Boeing aircraft windshield

The Boeing aircraft windshield electrical heating terminal initially installed a screw/lug (manufactured by PPG Aerospace) type of connector, which had a history of damage to the solder joints inside the windshield terminal block. These were the primary cause of the smoke and odour events in the flight deck window.

Boeing SB (747-30-2081-Rev. 5, 2017) and the FAA AD recommendations were to replace the screw/lug type of connectors with the pin/socket type of power connectors produced by GKN or PPG Aerospace. These windshields with pin/socket terminal blocks did not incorporate solder joints, which causes arcing ignition source in a loose cross-thread screw/lug electrical terminal. The heat caused by the loose terminal exceeded the rated melting point of the solder that was resulting in high voltage arcing that might damage windshield glass. It should be noted that the 747-8 was not included because the pin/socket terminal design was incorporated in production prior to service.

The FAA released 2012-13-09 (747), 2012-25-01 (757/767/777), and 2012-25-03 (757).

These ADs were addressed to increase the required repetitive inspections as the FAA determined that these windshields do not provide an acceptable level of safety and replacing windshields with pin/socket heat terminals is not terminating action for required repetitive inspections.

The windshield heating terminal block (part number U16108647) was installed on the Incident Aircraft was the pin/socket terminal design that included a power braid wire crimped inside the connector as shown in figures 11 and 12 which is intended to be more reliable.

Window Teardown Analysis

The electrical arcing originated from the integrated power braid wire joint crimped at the connector base leading to degraded electrical conductivity within this terminal. The results from the CT scan images revealed that fractures of wire strands at a crimp point within the pin base caused the electrical resistance and heat buildup which generated electrical sparks and smoke.

Conclusions

From the evidence available, 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 particular organization or individual.

Findings

(a) The Aircraft was certificated, equipped, and maintained in accordance with the requirements of the *Civil Aviation Regulations* of Luxembourg.

(b) The Aircraft was airworthy when dispatched for the flight, and there was no defect or malfunction detected that could have contributed to the Incident.

(c) Both pilots were licensed and qualified for the flight in accordance with the requirements of the *Civil Aviation Regulations* of Luxembourg.

(d) Both pilots were well-rested prior to the flight and fit for the flight.

(e) The Commander was the pilot monitoring (PM) and the Copilot was the pilot flying (PF).

(f) The NTSB issued safety recommendations *A-07-49* and *A-07-50* to the FAA in 2007 to approve the service bulletin for installation of the redesigned heat terminal block on Boeing 767 aircraft as well as to issue AD to replace the windshield heat terminal block on all Boeing 747, 757, 767 and 777 aircraft with the Boeing service bulletins.

(g) The FAA issued airworthiness directive 2012-13-09 (747), 2012-25-01 (757/767/777), and 2012-25-03 (757) to include repetitive inspections of electrical heat terminals on the left and right windshield, as well as allow replacing an affected windshield equipped with different electrical connections, which would terminate the repetitive inspections for that windshield. They issued this AD to prevent smoke and fire in the flight deck, which could lead to loss of visibility, and injuries to or incapacitation of the flight crew.

(h) The Aircraft manufacturer was aware of windshield heating terminal block smoke and fire incident since the year 2006.

(i) The manufacturer issued service bulletin number 747-30-2081 in August 2006, currently, at revision level 5 issued in January 2017, that includes inspection for the screw/lug terminal design and allows windshield replacement with the pin/socket terminal. The incident aircraft, a 747-8, incorporated a similar pin/socket design during production prior to entry into service.

(j) On 16 January 2019, a B747-8F aircraft operated by the same Operator reported a similar incident with the R1 window windshield heating the electrical terminal block suffered smoke and electrical sparks.

Causes

The Air Accident Investigation Sector determines that the cause of the smoke and fire in the R1 window terminal block was the defective windshield thermal (anti-ice) heating electrical pin/socket terminal block consisting of a power braid wire crimped at the base pin.

Contributing Factors

The Air Accident Investigation Sector identifies the following contributing factors:

(a) The window manufacturer’s actions to eliminate the manufacturing defect of electrical blocks assembled on aircraft windows during the manufacturing process were not adequate.

(b) The FAA ADs and Boeing SBs were not effective to detect poor or weak thermal (anti-ice) electrical terminal blocks installed on the Boeing aircraft windows.

(c) The NTSB safety recommendations A-07-49 and A-07-50 were not effective to eliminate the defective terminal.

Safety Recommendations

Boeing Safety Actions

(a) Discontinued the supplier (GKN) Boeing will consider failure mode with potential future suppliers

(b) Developing possible inspection(s) that may be useful in identifying a loose or problematic connection before an arcing event occurs. (Four different inspection techniques which include a resistance-shake check for a loose connection, insulation resistance check for moisture ingression, current check to indicate a loose connection, and a thermal image sweep looking for terminal overheating. The work is ongoing to determine the most effective technique(s) in identifying a problematic terminal prior to an event)

(c) Implemented the new industry standard quick disconnect type connections on newer designs. (Quick disconnects were first implemented on the 787 flight deck windows and have worked successfully without incident. Boeing plans to use similar quick disconnect type connectors on future new programs. Due to interchangeability requirements, there is no plan at this time to retrofit this design change on the 747 windshields, but Boeing continues investigating in-service inspection techniques to minimize additional failures of the pin/socket design.

Safety Recommendations

The Air Accident Investigation Sector will monitor Boeing safety actions implementation in coordination with NTSB as well monitor for any future occurrence with similar causes.

The Federal Aviation Administration of the United States (FAA)

SR01/2023

Oversight the failure mode technique(s) with future potential suppliers and the most effective technique(s) in identifying a problematic terminal prior to an event.

The Boeing Company

SR02/2023

Release a service bulletin when the most effective technique(s) to identify a problematic terminal prior to an event.

This Summary Report is issued by the:
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The United Arab Emirates

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