Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation

AO-2009-027

Final

# In-flight fire
# 427 km south-west of Guam
# 10 June 2009
# Airbus A330-202
# VH-EBF

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In-flight fire – 427 km south-west of Guam – 10 June 2009 – Airbus A330-202 – VH-EBF

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**Abstract**

On 10 June 2009, the flight crew of a Jetstar Airways Airbus A330 aircraft, registered VH-EBF, flying from Osaka, Japan to Gold Coast, Queensland, observed flames at the base of the right main windshield. The fire had initiated from an electrical connection to the windshield heating system. The fire was extinguished by the flight crew and the flight diverted to Guam.

The ATSB investigation concluded that the overheat failure of the right windshield was related to the use of a polysulfide sealant (PR1829) within the body of the electrical connector terminal block. Use of that sealant had created conditions within the block which led to unintended electrical heating effects during operation of the windshield heating system. Consequentially, this had developed into the thermal breakdown of the sealant and the initiation of a localised fire.

Subsequent to the occurrence involving VH-EBF, similar windshield overheating events in other Airbus A330 and A320 aircraft were reported. The aircraft manufacturer’s technical examination of those windshields concluded that contact between the braided wires within the terminal block, as well as the unintended migration of the PR1829 sealant had probably combined to trigger the reported events.

Safety action from the aircraft manufacturer included a program to identify and replace all windshields that had been produced using the PR1829 polysulfide sealant within the electrical connector terminal block assembly. That program was initiated in early 2010 and extended to the replacement of approximately 1,500 units within the world-wide Airbus fleet. The ATSB have been advised that due to limited fleet-wide completion of the windshield replacement program, the European Aviation Safety Authority (EASA) is considering the implementation of an Airworthiness Directive (AD) that will require all European operators of applicable Airbus aircraft to comply with the Airbus windshield replacement program. The ATSB were also advised that the windshield replacement program was completed across the Qantas Group of applicable aircraft in April 2011, and that windshields fitted to other Australian operated A330 aircraft are not affected by the replacement program.

# THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

**Purpose of safety investigations**

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

**Developing safety action**

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

# TERMINOLOGY USED IN THIS REPORT

**Occurrence:** accident or incident.

**Safety factor:** an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

**Contributing safety factor:** a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

**Other safety factor:** a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

**Other key finding:** any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

**Safety issue:** a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

**Risk level:** the ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

**Safety action:** the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

# FACTUAL INFORMATION

## History of the flight

On 10 June 2009 at 1205 Coordinated Universal Time (UTC[1]), an Australian registered Airbus 330-202 aircraft, VH-EBF, operated by Jetstar Airways, departed Kansai International Airport, Osaka, Japan on a scheduled passenger transport service to Gold Coast Airport, Queensland. On board the aircraft were 185 passengers, 13 cabin crew and two flight crew (captain and copilot). Two other pilots were also onboard as observers and were seated behind the flight crew.

The flight crew reported to the Australian Transport Safety Bureau (ATSB) that the departure, climb-out and initial cruise from Osaka was normal, with the aircraft established at the assigned flight level of FL390 (39,000 ft) by 1235.

At 1523, approximately 3 hours and 17 minutes into the flight, the flight crew noticed a burning odour on the flight deck. The captain called the cabin service manager by intercom to establish whether the smell was coming from the passenger cabin. The report from the cabin manager indicated there was a burning smell evident, but neither smoke nor a detectable source was able to be identified. When the aircraft was approximately 427 km to the south-west of Guam, an ECAM[2] message was displayed to the flight crew, indicating cautions regarding the right windshield heating system. The captain assumed control of the aircraft from the copilot, and instructed the copilot to commence the ECAM actions.

At 1524, immediately following the conversation with the cabin manager, there was a loud bang and a bright flash of light in the flight deck, followed by a small amount of smoke. The crew then observed a small fire in the bottom right corner of the right windshield (Figure 1). The flight crew and the observing pilots immediately donned their oxygen masks and conducted the 'windshield heat abnormal' procedure.

Despite these actions the fire continued. The copilot initially attempted to smother the fire by using heat resistant gloves that were located on the flight deck. This attempt was unsuccessful. The copilot then used a portable fire extinguisher[3] by applying several short bursts to the area of the fire. This action extinguished the fire.

A decision was made to divert and land at the nearest suitable alternate destination, which was Guam International Airport, Guam. A PAN[4] call from the captain to

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1 The 24-hour clock is used in this report to describe the time of day, Coordinated Universal Time (UTC), as particular events occurred. The flight crossed two different time zones. The local times differed from UTC by +9 to +10 hours, depending on location.

2 ECAM - electronic centralised aircraft monitoring.

3 The fire extinguisher contained bromochlorodifluoromethane (also known as BCF or Halon 1211) that was suitable to combat fires from flammable liquids and gases, ordinary combustibles and energised electrical equipment.

4 An internationally recognised radio call announcing an urgency condition which concerns the safety of an aircraft or its occupants, but where the flight crew does not require immediate assistance.

Guam Centre air traffic control (ATC) requested an immediate diversion and descent clearance to Guam. When the clearance was not forthcoming, the flight crew elected to make a MAYDAY[5] call. ATC approved the diversion and cleared the aircraft to descend.

The approach and landing charts for Guam were located in a cupboard that was remote from the operating crew and required one of the observing pilots to locate and pass the charts to them. The cabin crew and passengers were kept informed of the emergency and the diversion to Guam. The cabin service manager later reported the public address (PA) communications from the flight crew were difficult to understand during the emergency, due to the muffling and distortion effects arising from the crews' oxygen mask microphone systems.

The flight crew reported that other than the windshield anti-icing and defogging system, no other aircraft systems were affected by the fire. Throughout the descent and landing at Guam, the operating flight crew remained on oxygen. However, during the approach to Guam, one of the two observer pilots momentarily removed their oxygen mask and was able to detect the presence of residual fumes from the fire. It was reported that the fumes remained evident for the remainder of the flight.

At 1624 the aircraft landed on runway 06R, where emergency services were in attendance. Emergency services verified the aircraft was safe to taxi to the airport terminal, after which the passengers disembarked via a terminal aerobridge.

**Figure 1: VH-EBF undergoing repair at Guam showing the location of the right windshield**


## Injuries to persons

There were no injuries to any of the passengers or the crew.

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5 Mayday is an internationally recognised radio call for urgent assistance.

# Aircraft information

## Aircraft general

**Table 1: General aircraft details**

| | |
|---|---|
| Operator | Jetstar Airways |
| Aircraft manufacturer | Airbus |
| Aircraft model | A330-202 |
| Serial number | 853 |
| Australian registration | VH-EBF |
| Year of manufacture | 2007 |
| Date of Australian registration | 3 August 2007 |
| Certificate of Airworthiness | Issued on 24 August 2007 |

## Aircraft specific maintenance

At the time of the incident, the airframe had operated for a total of 9,447 hours and through 1,422 flight cycles. The aircraft underwent a 'C' maintenance check on 16 December 2008 and an 'A' maintenance check on 6 May 2009 (at 8,993 hours and 1,352 cycles). During these 'A' and 'C' checks, an inspection of the cockpit environment was performed, including a detailed examination of the windshield integrity and connections. The operator's records of those inspections showed no relevant evidence of windshield damage or repair activity.

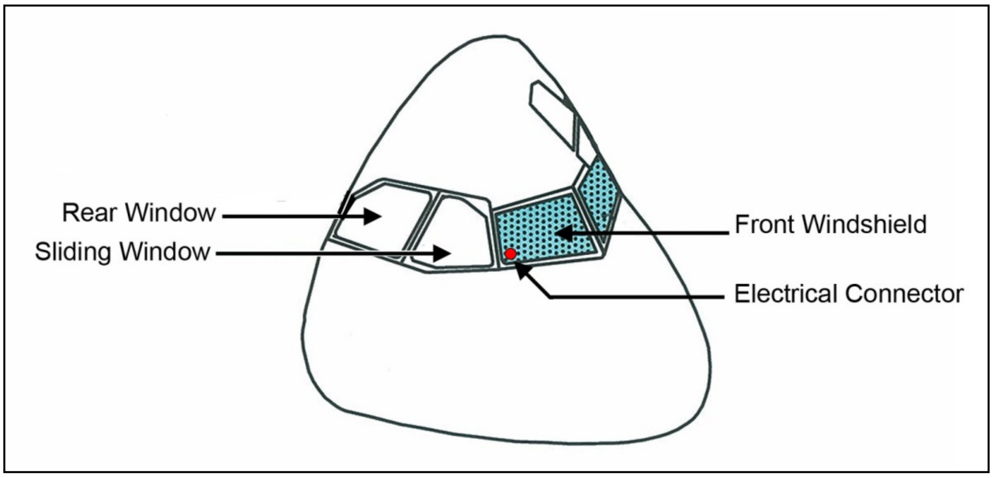
## Windshield anti-icing and defogging system

### *Windshield*

The aircraft's cockpit was equipped with two forward windshields, two fixed windows and two sliding windows (Figure 2). The aircraft's windshield anti-icing and defogging system was designed to enable clear visibility in icing or fogging conditions. Window heating was automatically activated upon first start-up of the aircraft's engines (left or right) and stopped at the last engine shutdown. The crew could also control the operation of the window heat by using a pushbutton switch[6] to override the automatic operation of the system and apply continuous full heating.

[6] The 'Probe/Window Heat' button is located on a central overhead panel within the flight deck.

**Figure 2: A330 window configuration**




Each windshield was principally comprised of a laminated construction of strengthened glass panels. A thin layer of transparent, electrically conductive material[7] that functioned as a heating element was incorporated between the outer glass laminates. A corner-mounted terminal block and threaded connector enabled electrical power to be supplied to the heating element wires within each windshield. The electrical connector terminal block comprised an outer case of non-conductive polymeric material, upon which was mounted a socket and integral silicone insulating plug that isolated the heating system and sensor wires from one another. Beneath the socket, the terminal blocks were filled with a polysulfide sealant to provide additional protection against the ingress of moisture and condensate during service. Both the braided power and braided sensor wires were crimped to the socket pin contacts for insertion into the connector housing.

### *Window heat computer*

The windshield heating system included two fully independent ‘window heat computers’ (WHCs) that monitored windshield temperatures and heating element currents. The WHCs regulated the windshield temperatures – keeping them between 35°C and 42°C during flight, and could also remove power to the heating system in the event of a fault. Sensors built into the windshield structure ensured correct temperature regulation by providing feedback to the WHCs. Each WHC included internal memory for automatic storage of detected faults. The WHCs were powered by 115V AC[8] and 28V DC[9] from the aircraft’s systems, and supplied 200V AC to the window heating elements. Up to 3.6 kilowatts of electrical power from the WHCs could be supplied to the conductive layer of each windshield, via the electrical connector and braided wiring within the connector and terminal block housing.

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7 A transparent and electrically conductive coating of indium tin oxide had been incorporated into the windshield.

8 (AC) Alternating Current.

9 (DC) Direct Current.

## Damage to the aircraft

Immediately following notification of the occurrence, investigators from the ATSB and engineering staff from the aircraft operator's maintenance provider travelled to Guam to inspect the aircraft and commence an investigation. From the initial inspection it was evident that the damage was limited to the right windshield and the number-2 window heat computer (WHC).

### Windshield

The damaged right windshield[10] was produced by Saint-Gobain Sully, France, in February 2007, and had been installed during construction of the aircraft. Inspection in Guam showed severe burning and melting of the right side windshield terminal block housing and minor heat damage to the glare shield and wire conduit around nearby loudspeaker wiring (Figures 3 and 4). The electrical plug from the window heat computer was firmly secured to the windshield connector and was undamaged. There was no evidence of loose fitting between the connector and the terminal block.

A small amount of smoke residue was present on the inner surface of the windshield adjacent to the terminal block. No further damage was observed on any nearby equipment or wiring. No heat damage was observed on the aircraft's windshield glass or windshield mounting structure. No damage or evidence of excessive heat was observed on the windshield heat supply wiring, left side windshield, or fixed or sliding windows.

Following the ATSB's on-site examination, and due to the lack of appropriate overhaul and repair facilities in Australia, the windshield was packaged and sent to the manufacturer for further detailed inspection (see the section titled *Additional testing*).

### Post flight report

The A330 Central Maintenance Computer (CMC) directly monitored and identified faults within the aircraft's systems. Faults were divided into three separate categories (Level 1 to Level 3) and depending on the hierarchy, could be displayed to the flight crew using the electronic centralised aircraft monitor (ECAM). The ECAM provided information to the crew on the status of the aircraft and its systems using two display units on the flight deck.

A maintenance report on the occurrence flight was automatically printed as soon as the aircraft had landed in Guam. This document (known as the Post Flight Report, PFR) was normally the main source of information used by the operator to initiate trouble shooting and to decide on the required maintenance actions. The PFR contained a record of events advising maintenance engineers which aircraft systems had exhibited fault behaviour.

When printed, the occurrence flight PFR indicated that a fault within the number-2 WHC was recorded at 1523. At that time, the ECAM message 'A. ICE R WSHLD

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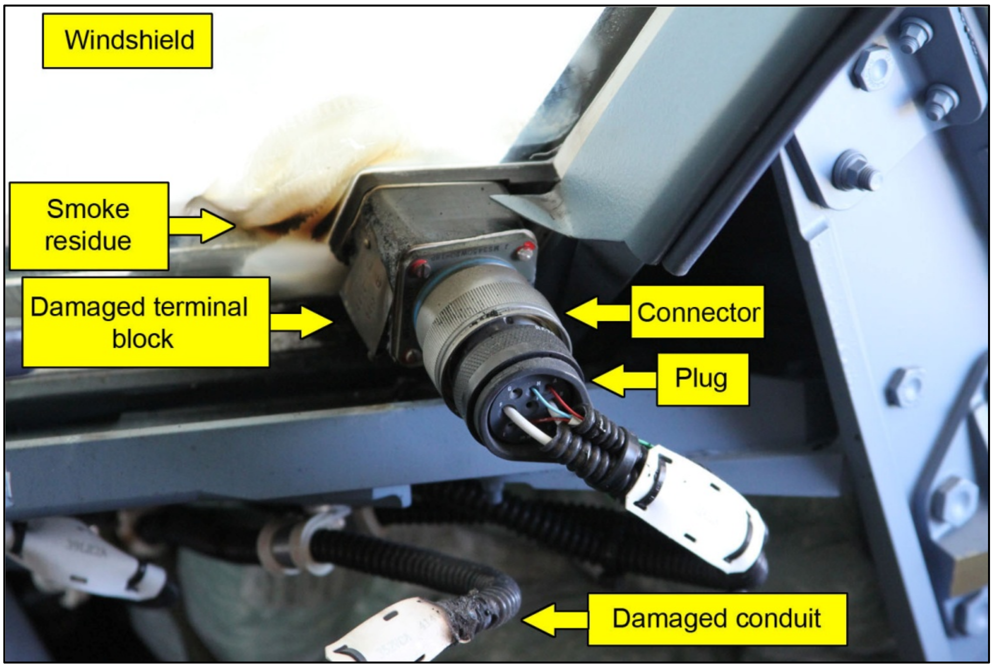
[10] Part Number SPS A340-1-4-1A, Serial Number 3594.

HEAT' was displayed to the flight crew. A 'hard fault'[11] with the number-2 WHC was recorded a short time later at 1524.

## Window heat computer

Examination of the exposed wiring and conduit between the windshield and the number-2 WHC did not reveal any evidence of overheating or electrical arcing. During the investigation, the wiring passed serviceability tests. All relevant circuit breakers were inspected and had remained closed. The WHC was removed from the aircraft and sent to its manufacturer, Zodiac Aerospace, France, for examination and analysis (see the section titled *Additional testing*).

**Figure 3: Windshield heat electrical connector and terminal block housing (in situ)**




[11] A hard-fault indicates physical damage to a circuit or electronic component.

**Figure 4: Close-up view of the melted terminal block**

## Personnel information

At the time of the occurrence, the co-pilot was in control of the aircraft, with the autopilot engaged and the aircraft established in the cruise at FL390. Table 2 summarises the operational qualifications and experience of the flight crew at the time of the occurrence.

**Table 2: Flight crew qualifications and experience**

| | Captain | Copilot |
|---|---|---|
| Licence category | ATPL | ATPL |
| Instrument rating | Command | Command |
| Last Class-1 medical | 14 July 2008 | 16 March 2009 |
| Total flying hours | 14,100 hours | 5,824 hours |
| Total on A330 | 3,300 hours | 1,402 hours |
| Total last 30 days | 45 hours | 88 hours |
| Total last 90 days | 169 hours | 216 hours |

## Meteorological information

The prevailing local weather conditions at Guam were communicated by Guam ATC to the flight crew of the aircraft in preparation for their arrival. The METAR[12]

12 Routine aerodrome weather report issued at fixed times, hourly or half-hourly.

weather report for Guam indicated favourable landing conditions, with an easterly breeze at 3 kts, unrestricted visibility and few[13] clouds to 1,800 ft.

## Flight recorders

The aircraft was fitted with three flight recorders:

- cockpit voice recorder (CVR)
- digital flight data recorder (DFDR)
- quick access recorder (QAR).

The CVR and DFDR were mandatory recorders, while the QAR was an optional recorder that the operator had chosen to fit to all its A330 aircraft. Information recorded by the CVR and DFDR was stored in crash-protected modules.

The CVR recorded the total audio environment on the flight deck of the aircraft, which included crew conversations, radio transmissions, switch activations, system alerts and control movements. The CVR retained the last 2 hours of information in solid-state memory, operating on an endless-loop principle.

The DFDR and QAR recorded aircraft flight data parameters. The DFDR contained data from over 81 hours of aircraft operation, comprising the occurrence flight and nine previous flights. The DFDR used solid-state memory as the recording medium and operated on an endless-loop principle.

Investigators from the ATSB supervised the removal of the CVR and DFDR from the aircraft in Guam and their dispatch to the ATSB's technical facilities in Canberra. Both the CVR and DFDR were successfully downloaded by the ATSB and the operator later provided a copy of the QAR data. Table 3 provides a sequence of events prepared from data obtained from the aircraft's recorders, and supported by crew interviews. A plot of the DFDR data relative to the event within the occurrence flight is shown at Appendix A.

**Table 3: Occurrence flight sequence of events**

| Time (UTC) (hh:mm:ss) | Time relative to event (hh:mm:ss) | Time after takeoff (hh:mm:ss) | Event |
|---|---|---|---|
| 12:05:29 | -03:22:05 | 00:00:00 | Takeoff at Kansai (Japan) |
| 12:35:41 | -02:51:53 | 00:30:12 | Aircraft reached top of climb FL390 |
| 15:23:13 | -00:04:21 | 03:17:44 | Burning smell first detected on the flight deck |
| 15:23:32 | -00:04:02 | 03:18:03 | Master caution alert (first) |
| 15:24:39 | -00:02:55 | 03:19:10 | Loud 'bang', flash of light from the right windshield and crew exclamation |
| 15:24:49 | -00:02:45 | 03:19:20 | Master caution alert (second) |

13 Cloud cover is normally reported using expressions that denote the extent of the cover. The expression Few indicates that up to a quarter of the sky was covered, Scattered indicates that cloud was covering between a quarter and a half of the sky. Broken indicates that more than half to almost all the sky was covered, while Overcast means all the sky was covered.

| | | | |
|---|---|---|---|
| 15:25:01 | -00:02:33 | 03:19:32 | Flight crew put on oxygen masks |
| 15:25:58 | -00:01:36 | 03:20:29 | Window Heat pushbutton selected ‘ON’ (QRH action) |
| **15:27:34** | **00:00:00** | **03:22:05** | **Fire first observed by flight crew** |
| 15:28:34 | +00:01:00 | 03:22:45 | PAN call to air traffic control |
| 15:30:04 | + 00:02:30 | 03:24:33 | Fire extinguisher used |
| 15:31:05 | +00:03:31 | 03:27:36 | MAYDAY call to air traffic control |
| 15:32:02 | + 00:04:28 | 03:26:33 | Descent commenced |
| 16:14:00 | +00:46:26 | 04:08:31 | Landing at Guam |

## Other windshield events

Following the occurrence involving VH-EBF, the ATSB was alerted to several other incidents also associated with electrical arcing and burning from the vicinity of the windshield connectors on Airbus A320 and A330 aircraft. Three of the failures are summarised below.

> All Nippon Airways: On 19 May 2009, during cruise at 37,000 ft, the flight crew of a Japanese-registered A320 aircraft reported that a loud ‘bang’ was heard followed by the immediate observation of sparks and smoke from the left windshield. In response, the pilots put on oxygen masks per the ‘Smoke/Fumes/Avionics Smoke’ checklist and continued the flight.
>
> Asiana Airlines: On 2 July 2009, the flight crew of a South Korean-registered Airbus A330 aircraft reported a burning smell and electrical arcing around the right windshield heating connector. The aircraft manufacturer reported that ‘power to the windshield heater was cut by the WHC’. The aircraft operator reported that the post-flight report recorded a ‘R WSHLD/WHC 2 fault, with the corresponding ECAM message ‘A.ICE R WSHLD HEAT’. After landing, that windshield was also sent to the component manufacturer (see section titled *Additional testing*).
>
> Sichuan Airlines: On 9 August 2009, 21 minutes after takeoff, the flight crew of a Chinese-registered Airbus A320 aircraft reported a burning smell and electrical arcing near the left windshield heating connector. The A.ICE L WINDOW HEAT ECAM message was triggered and a portable fire extinguisher was used in the vicinity of the windshield connector. That windshield was subsequently removed from the aircraft and sent to the component manufacturer for examination (see section titled *Additional testing*).

In addition, on 22 March 2011, a subsequent occurrence was reported to the ATSB involving an Australian-registered Qantas Airbus A330 aircraft[14]. In that event, the flight crew reported that during cruise at 39,000 ft, electrical arcing and small flames appeared in the vicinity of the left windshield heating connector. The crew donned oxygen masks and extinguished the fire using the BCF fire extinguisher. An ECAM message fault ‘A.ICE L WSHLD HEAT’ prompted the crew to action the

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[14] ATSB Aviation Safety Investigation Report AO-2011-041, Airframe Event – Airbus A330-203, VH-EBL, 365 km NW Cairns, 22 March 2011.

appropriate checklist. Throughout the remainder of the flight there were four more occasions when the crew were required to extinguish flames from electrical arcing.

The aircraft manufacturer indicated to the ATSB that at the time of that occurrence (22 March 2011), a total of 19 windshield electrical connector terminal block overheat events had occurred; 12 on the A320 family of aircraft, and seven on A330 aircraft (Table 4). Service records for each of the affected aircraft indicated the time-to-failure from manufacture had been indiscriminate, with no particular correlation identified.

**Table 4: Reported service history of windshields that had connector block overheat failures**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **A330** | **Cycles**<br>**Hours** | 213<br>1,630 | 1,422<br>9,447 | 1,126<br>3,775 | 579<br>4,189 | 2,228<br>4,556 | 1,343<br>8,306 | u/k<br>400 | | | |
| **A320** | **Cycles**<br>**Hours** | 4,056<br>7,005 | 1,327<br>3,391 | 4,157<br>6,771 | u/k<br>3,879 | 4,339<br>7,252 | 4,409<br>6,208 | 4,804<br>8,039 | 6,131<br>9,914 | 2,139<br>3,232 | 12,258<br>14,883 |
| **A319** | **Cycles**<br>**Hours** | u/k<br>u/k | | | | | | | | | |
| **A321** | **Cycles**<br>**Hours** | 851<br>2,570 | | | | | | | | | |

# Additional testing

After the windshield from VH-EBF had been removed from the airframe and prior to any disassembly taking place, the terminal block was inspected by the ATSB using radiographic techniques. The x-ray inspections permitted an understanding of how the wires were organised inside the terminal block, with one of the braided wires showing severe localised damage. A schematic diagram of the terminal block and the pin connections is shown at Figure 5, with a radiograph showing the wiring damage at Figure 6.

Due to the unavailability of appropriate repair and overhaul facilities in Australia, the damaged windshield was sent to its manufacturer in France. Accredited representatives[15] from the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) oversaw the examination and inspections on behalf of the ATSB.

15 ICAO Annex 13: A person designated by a State, on the basis of his or her qualifications, for the purpose of participating in an investigation conducted by another state.

**Figure 5: Terminal block connector pin layout; pins B and F supplied power to the inter-laminate heating film and pins A, C, D and H were connected to the temperature sensors**

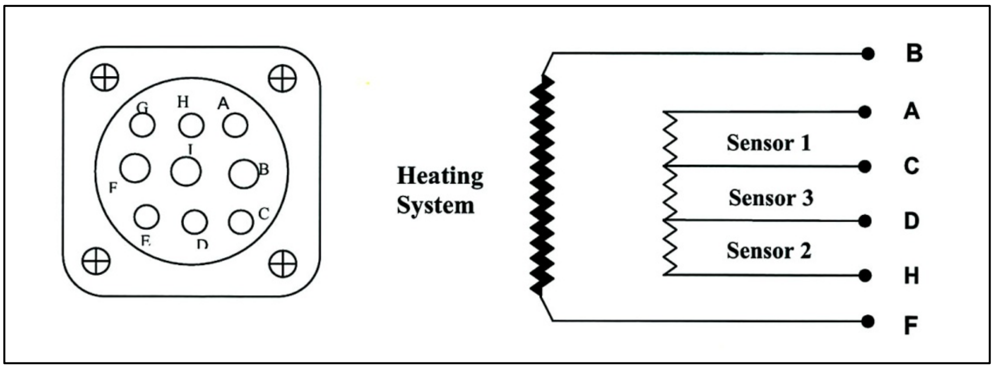
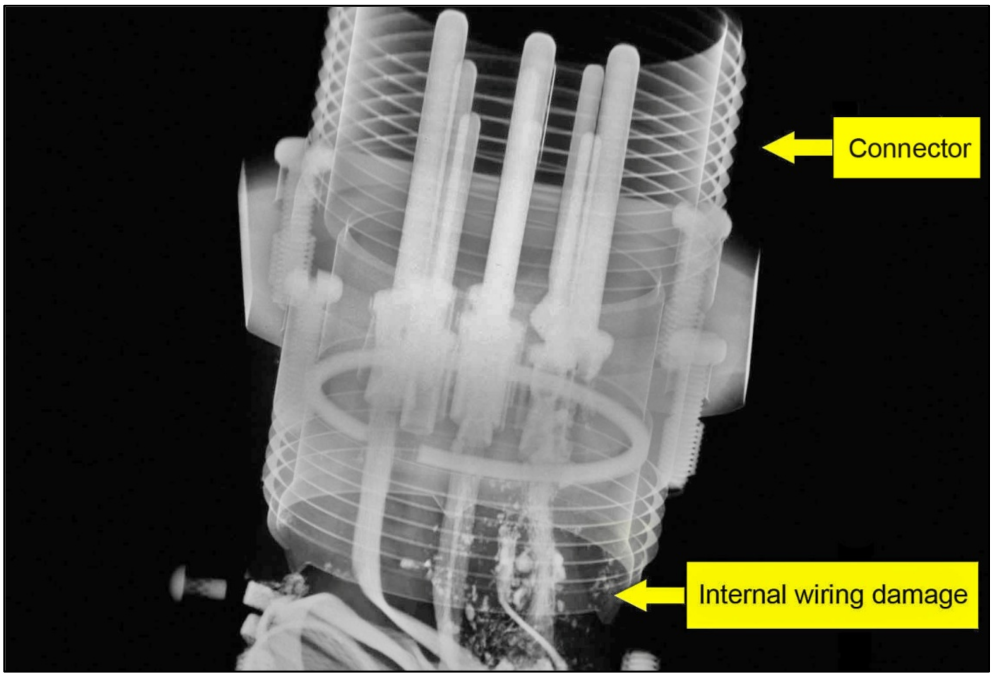



**Figure 6: Radiograph showing disruption to the internal wiring within the terminal block**




### *Windshield terminal block from VH-EBF*

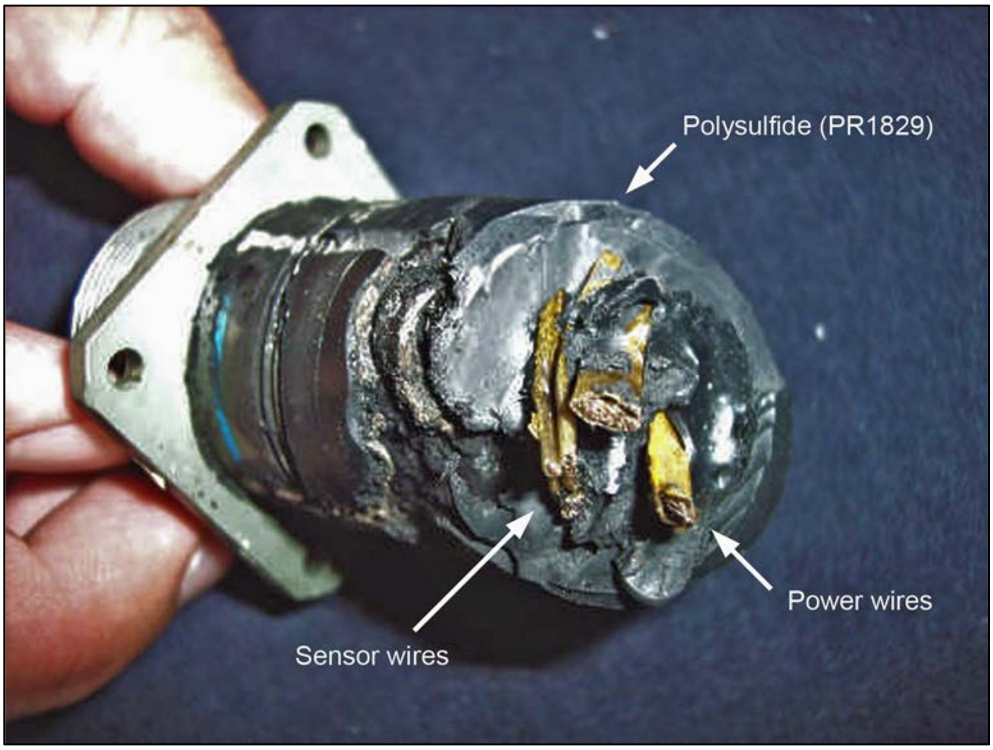
The following observations from the examination and analysis undertaken by the manufacturer were reported to the ATSB:

- In order to visually examine the physical condition of the power and sensor wiring, the terminal block was dismantled from its windshield mounted position and then destructively sectioned. That action showed that a plug of polysulfide sealant (PR1829) had been used to encase the wiring within the terminal block (Figure 7). The sectioning also showed that the silicone insulator surrounding the braided power wires (pin B) had partially burnt away from the effects of electrical arcing (Figure 8).
- The polysulfide sealant was removed from around the wire bundle to expose the general condition of the wires. Contact pin B that formed part of

the electrical power circuit was revealed to have fragmented in a way consistent with extreme overheating damage (Figure 9).

- The aircraft manufacturer indicated that a polysulfide sealant (PR1829)[16] had been used to fill the terminal block for windshields manufactured between January 2007 and October 2008. For those windshields (1,500 in total), the terminal block cavity was filled with sealant prior to final assembly. The sealant's purpose was to prevent moisture and condensate from entering the terminal block. Of the windshields that had sustained an electrical failure (19 in total), it was indicated that all had been manufactured with a filling of PR1829 sealant.

**Figure 7: Partially dismantled windshield terminal block from VH-EBF with wiring shown encased in polysulfide sealant**




[16] PR1829 is a rapid curing compound commonly used as an aircraft windshield and canopy sealant.

**Figure 8: Partially dismantled windshield terminal block from VH-EBF showing concentrated burning of the silicone insulator that surrounded contact pin B**

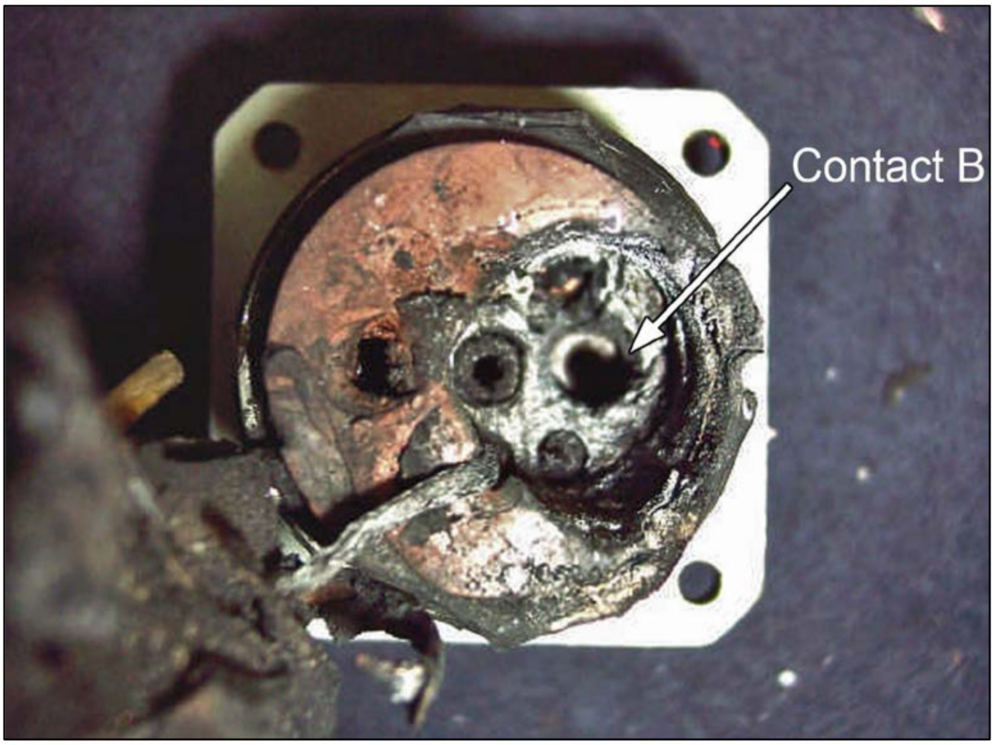
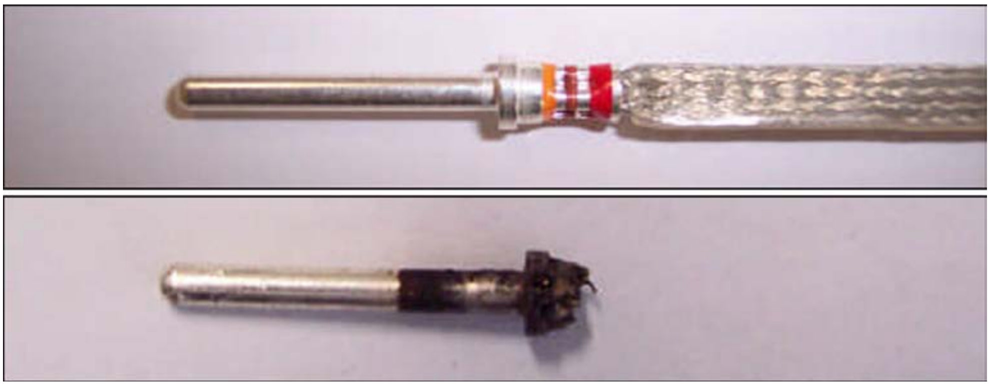



**Figure 9: Comparison of electrical terminal block connector pins: burnt pin B from VH-EBF (lower) and that from an exemplar unit (upper)**



### *EADS test program*

As a result of the windshield heating system failures, the aircraft manufacturer commissioned the European Aeronautic Defence and Space Company (EADS) to perform further specialist testing and detailed examination of electrical terminal blocks from windshields that had electrically failed during service. Two separate reports detailing the analyses of the electrical connector failure from the Chinese-registered Airbus A320[17] aircraft and the Korean-registered A330[18] were provided to the ATSB.

A number of discrete key features were identified in the reports, however in both cases it was established that a dark substance had migrated inside the crimping area of the electrical connector pins. Crimping is the compression of a terminal around the conductor of a wire, which mechanically secures the two and provides an electrical path of low resistance.

Subsequent chemical analyses of that dark substance revealed the presence of carbon, silicon and sulphur constituents; all of which were present in the polysulfide sealant (PR1829) that had been used as the terminal block filling agent.

A transverse metallographic cross-section of the crimped region from a connector pin is shown at Figure 10. As noted in the extract[19] below, while the connector pin and braided copper wires had been crimped, sufficient residual space remained after that process to allow PR1829 to migrate into the voids between the wire strands.

> A critical aspect of connector installation is the contact conductor interface... The degree of compression is a significant factor in connector reliability. It is imperative to use only the recommended degree of compression, as too low a compression may result in high contact resistance, resultant higher power dissipation, a rise in temperature and subsequent degradation of the insulating material. The increased temperature may further oxidise the contacts, thus raising the contact resistance and eventually melting the insulating material...
>
> Several conditions are known to be contributing factors to connector failures, these may include:
>
> - short and long-term electrical overload conditions
> - presence of conductive contaminants
> - prolonged exposure to moisture
> - crimping problems. [19]

Published literature indicates that an effective crimp connection should amount to a 'cold weld' of the parts being connected and should contain negligible voiding and space between the compressed connector and wires. Figure 11 shows further detail of PR1829 that had migrated into the voids within the crimped area of a connector.

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17 EADS Innovation Works Metallic Technologies and Surface Engineering, report identification: 2009-11971/1-IW/MS/MF, dated 11 December 2009.

18 EADS Innovation Works Metallic Technologies and Surface Engineering, report identification: 2009-11971/3-IW/MS/MF, dated 18 December 2009.

19 Martin, P. L. (1999). *Electronic Failure Analysis Handbook*, McGraw-Hill, (pp 17.37-17.43).

Figure 10: Metallographic cross-section through a connector pin displaying only partial compaction of the copper wire strands and migration of PR1829 sealant between the wires

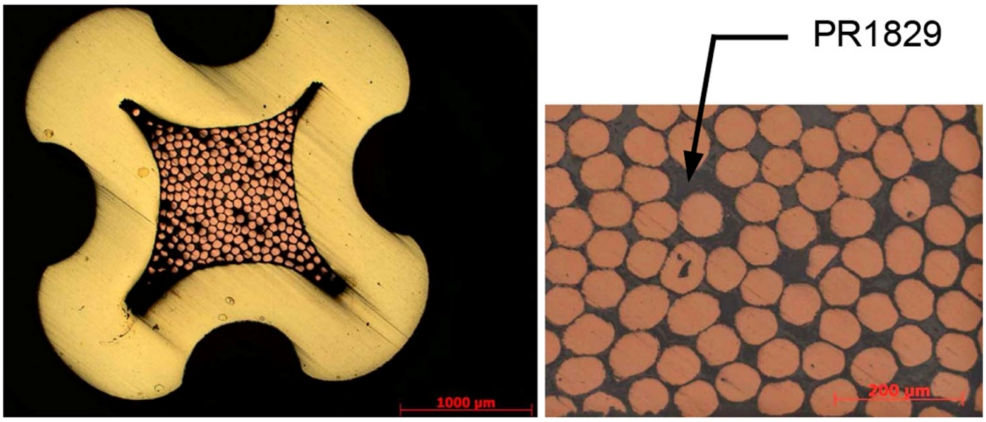
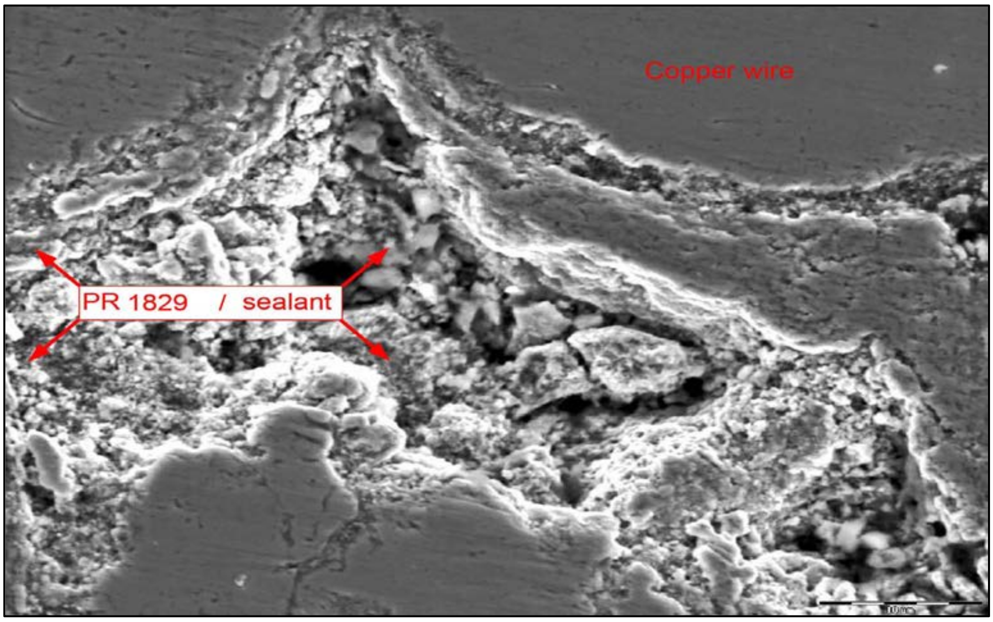



Figure 11: Scanning electron image showing the presence of PR1829 sealant between the individual copper wires of the braid




## Window heat computer (WHC) inspection

It was reported to the ATSB that upon opening of the number-2 WHC's external case, some internal electrical circuits exhibited damage to discrete components and circuit boards. Based on that damage, the WHC manufacturer concluded that excessive voltage from the windshield temperature sensor wires had been conducted through to the WHC, and upon exposure to that voltage, the internal components and circuitry became damaged from electrical overstress. It was also concluded that the last 'hard-fault' as contained in the PFR relevant to the number-2 WHC, was written by the central maintenance computer at 1524 when the WHC ceased functioning.

# Survival factors

## In-flight fires – advisory material

In their flight operations briefing notes[20], 'Managing In-Flight Fires', Airbus state that:

> An in-flight fire is probably the most serious in-flight emergency, and must be brought under control as soon as possible. Considering the crucial role that time plays in this type of emergency, it is imperative that no time is lost when attempting to extinguish the fire.
>
> Any fire, no matter how small, may rapidly become out of control, if not dealt with quickly.
>
> The first priority will always be to put it out.

Guidance material has also been published by the U.S. Federal Aviation Administration (FAA) for crew members and operators of transport category aircraft to assist in their preparation and training to deal with an in-flight fire. The FAA advisories were developed in response to recommendations made after the U.S. National Transportation Safety Board (NTSB) reviewed commercial aviation accidents involving in-flight fires during the period 1983 to 2000:

- FAA Advisory Circular AC 120-80 'In-flight fires'
- FAA Advisor Circular AC 20-42C 'Hand fire extinguishers for use in aircraft'

The advisory circulars are clearly written, and with respect to AC 120-80, provide a range of advice and information with particular emphasis on the importance of crew members (for both flight and cabin crew) recognising, assessing and taking immediate and aggressive action in response to the indications of an in-flight fire. The reports also emphasized the criticality of small in-flight fires that can spread and become uncontrollable if not immediately managed.

## Review of in-flight fire accident data

Although aircraft accidents arising from in-flight fires occur only very rarely, catastrophic events have occurred within the commercial aviation industry. Following the in-flight fire that lead to the collision into water of a Canadian-registered McDonnell Douglas MD-11 aircraft (Swissair 111) [21], the Transportation Safety Board of Canada (TSB) in its investigation of that accident, reviewed the historical data of in-flight fires involving high-capacity, transport-category aircraft. The TSB report noted that odour, smoke and/or fumes rarely developed into an in-flight fire; however, they also noted that if an in-flight fire were to develop, the time required to control or to suppress the fire was typically very brief.

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[20] Airbus Flight Operations Briefing Notes, Reference: FLT_OPS – CAB_OPS – SEQ 07 – REV 01 – SEP. 2006

[21] Transportation Safety Board of Canada, Aviation Investigation Report Number A98H0003, 'In-Flight Fire Leading to Collision with Water, Swissair Transport Limited, MacDonnell Douglas MD-11, HB-IWF, Peggy's cove, Nova Scotia, 5nm SW, 2 September 1998'.

The TSB data showed that in 15 transport-category accidents, between 5 and 35 minutes transpired between the detection of the first fire symptoms and the loss of the aircraft[22]. Although the circumstances varied in each of these occurrences, the research indicated that if an in-flight fire became uncontrollable, it could, in a very short time, lead to a total hull loss.

It should be noted that while the circumstances surrounding the VH-EBF occurrence and the Swissair 111 accident were not related, the loss of Swissair 111 critically demonstrates the need for immediate and decisive action when dealing with a developing in-flight fire.

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22 Flight Safety Foundation, 'Timely Detection, Response Improve Outcomes of In-Flight Fire Fighting', Vol. 36 No. 2 March – April 2001

# ANALYSIS

## Context

On 10 June 2009, an electrical fire developed in the cockpit of an Airbus A330-202 aircraft, registered VH-EBF. The first indication to the flight crew of the emerging problem was the detection of a burning smell, followed closely by a loud bang and a bright flash of light. Flames were then observed above the glare shield near the electrical connector at the lower corner of the right windshield. The fire originated from the electrical connector that formed part of the windshield's anti-ice and defogging system.

## Crew actions

When the fire was first observed, the response from the flight crew was immediate and in accordance with the aircraft manufacture's guidelines for managing in-flight fires. Had the fire persisted, then the situation could have posed a more significant challenge for the crew to manage within the confines of the cockpit environment.

Any kind of fire or smoke in the cockpit is a serious issue. Such an event can affect other aircraft systems, lead to a loss of visibility, provide a distraction, or incapacitate the crew and possibly lead to an accident. By first donning their oxygen masks, the potential risk to the crew of succumbing to the effects of toxic smoke and fumes was significantly reduced. The methods used to pursue and attack the fire by using both a heat resistant glove and then a portable fire extinguisher were effective in extinguishing the fire.

Once the fire risk had been addressed, the captain made an alert (PAN) call to air traffic control (ATC) requesting a diversion to Guam and for a descent clearance. When that descent clearance was not immediately forthcoming, a MAYDAY was declared and a clearance to divert and descend was provided.

## Electrical connector failure

The electrical connector fitting from the right windshield of VH-EBF showed severe thermal distress within the terminal block, which had melted and been partially consumed by fire. In normal operation, the connector supplied electrical power to the heating element between the glass laminates of the windshield.

A detailed examination of the connector fitting was performed by the aircraft and component manufacturers and showed that the braided wire that supplied power to the heating element had completely burnt through from the effects of electrical arcing and extreme overheating. The arcing and high-level heating was a result of short circuit conditions stemming from the localised breakdown in the insulating properties of the sealant. That breakdown was brought about due to internal heating effects between the conductors contained within the terminal block.

During the course of the investigation, the ATSB found that similar windshield problems had occurred in other aircraft in the global fleet. The manufacturer's investigation of those events revealed that several factors were most probably needed to trigger a windshield terminal block overheat event, including:

- the braided power and sensor wires being in close contact or folded within the PR1829 polysulfide sealant, and
- PR1829 sealant migrating into the crimping area of the electrical connectors within the terminal block – increasing the terminal resistance and the localised heating effects.

In the case of the connector pins examined by EADS, polysulfide sealant (PR1829) had migrated between the individual wire strands within the crimped power wire connector pins. PR1829 had been used on a batch of around 1,500 windshields to prevent moisture ingress into the terminal block. The crimped region within the connector pins should normally be devoid of PR1829 sealant – particularly between the conducting wires.

It is probable that insufficient compression of the pins during the crimping process may have provided a pathway for PR1829 sealant to migrate into the joint – increasing the strand-to-strand electrical resistance. While the investigation was unable to determine whether the sealant had migrated into the crimped connection during its manufacture, or during the process of terminal block thermal breakdown that preceded the fire, it was likely that the ingress of PR1829 into the connections would have increased the overall terminal resistance, and thus exacerbated the electrical heating effects in that area.

# FINDINGS

## Context

On a flight from Osaka Japan, to Gold Coast, Queensland, an Airbus A330 aircraft (VH-EBF) sustained a localised fire within the cockpit resulting from an electrical fault with the right windshield heating system.

From the evidence available, the following findings are made with respect to the in-flight fire and should not be read as apportioning blame or liability to any particular organisation or individual.

## Contributing safety factors

- Windshields manufactured with terminal block fittings containing polysulfide sealant (PR1829) have been shown to be predisposed to premature overheating failure that could lead to the development of a localised fire. *[Minor safety issue]*
- The electrical terminal block fitting from the right windshield of VH-EBF had been manufactured with a filling of PR1829 sealant.
- The electrical terminal block fitting from the right windshield of VH-EBF had sustained an electrical overheating failure that resulted in a fire developing within the cockpit environment.

## Other key finding

- The prompt and focused response from the flight crew was appropriate for the circumstances.

# SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

## Airbus

### In-flight fire

#### *Minor safety issue*

Windshields manufactured with terminal block fittings containing polysulfide sealant (PR1829) have been shown to be predisposed to premature overheating failure that could lead to the development of a localised.

### Action taken by Airbus

#### *Worldwide windshield replacement program*

In May 2010, the aircraft manufacturer issued a service bulletin (SB) A330-56-3009 that implemented a windshield recall, removal and replacement program. The program applied to a batch of approximately 1,500 windshields that had been manufactured between January 2007 and October 2008 where PR1829 polysulfide sealant had been used as a filling agent within the terminal block. The SB recommended a visual inspection of the left and right windshields to determine whether they were part of the batch containing PR1829 sealant. If identified, Airbus recommended that the affected windshields be replaced within 900 flight hours. Airbus reported to the ATSB that the airlines which had been initially affected by in-flight windshield overheat events would be prioritised in the replacement program.

Due to limited fleet-wide completion of the windshield retrofit program (SB A330-56-3009), Airbus have also indicated that they are in discussion with the European Aviation Safety Authority (EASA) with the view to implement an Airworthiness Directive that will require all European operators of applicable Airbus aircraft to comply with the windshield replacement program. Once released, it has been indicated that aircraft operators will be required to comply with the Airworthiness Directive within nine months from the date of its release.

### *Windshield manufacturing processes*

Airbus advised the ATSB that they were working with the windshield manufacturer in order to mitigate the possibility of recurrent windshield overheat events. Improvements to the windshield manufacturing processes include:

- polysulfide sealant (PR1829) is no longer used within the body of the terminal block
- the crimping process for electrical connectors has been improved
- the braided wire lengths inside the connector block and the electrical connector pin installation method have been optimised, which has resulted in the reduced potential for contact to occur between the power and sensor wires.

### *Information to operators*

On 11 June 2009, one day after the in-flight fire aboard VH-EBF, Airbus released an Operator Information Telex (OIT) [23] to all operators of their aircraft advising of the occurrence. A revision[24] to that OIT was subsequently released on 3 July 2009 advising operators that another windshield arcing/burning event had also occurred.

On 17 August 2009, a Flight Operations Telex (FOT) [25] was sent to all operators of Airbus A300, A310, A318, A319, A320, A321, A330, A340 and A380 aircraft that advised of the recent events where fire/arcing/burning/smoke was experienced in the cockpit environment from the apparent failure of the windshield heat connector. The FOT was directed to all flight operations departments of airlines that operated susceptible Airbus aircraft types. The FOT was aimed to ensure that crews applied the correct procedure in the event of electrical arcing, burning or smoke being experienced during flight.

# Jetstar Airways (the Qantas Group)

## In-flight fire

### *Minor safety issue*

Windshields manufactured with terminal block fittings containing polysulfide sealant (PR1829) have been shown to be predisposed to premature overheating failure that could lead to the development of a localised fire.

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23 Airbus reference SE 999.0051/09, Subject: ATA30 – Smoke in cockpit due to electrical failure of windshield heater connector, dated 11 June 2009

24 Airbus reference SE 999.0051/09, Subject: ATA30 – Smoke in cockpit due to electrical failure of windshield heater connector, dated 3 July 2009

25 Airbus reference SE 999.0066/09, Subject: ATA30 – Smoke in cockpit due to electrical failure of windshield heater connector, dated 17 August 2009

## Action taken by Jetstar Airways (the Qantas Group)

***Fleet wide inspection and windshield replacement program***

Following the incident involving VH-EBF, an inspection of all windshields from A330 aircraft that were operated by both Jetstar Airways and Qantas (the Qantas Group) was performed. The inspections commenced on 11 June 2009 and the ATSB were advised that all aircraft had been inspected within a 24-hour period. No defects associated with the occurrence were found.

The ATSB were also advised that the windshield replacement program (Airbus SB A330-56-3009) was completed across the Qantas Group of applicable aircraft in April 2011.

# Other Australian A330 aircraft operators

## In-flight fire

***Minor safety issue***

Windshields manufactured with terminal block fittings containing polysulfide sealant (PR1829) have been shown to be predisposed to premature overheating failure that could lead to the development of a localised fire.

## Action taken by other Australian A330 aircraft operators

The ATSB have been advised by the other Australian operators of Airbus A330 aircraft, Strategic Airlines and Virgin Australia, that the windshields installed in their aircraft were not included in the batch identified in Airbus Service Bulletin A330-56-3009.

# European Aviation Safety Authority (EASA)

## In-flight fire

***Minor safety issue***

Windshields manufactured with terminal block fittings containing polysulfide sealant (PR1829) have been shown to be predisposed to premature overheating failure that could lead to the development of a localised fire.

## Action taken by the European Aviation Safety Authority (EASA)

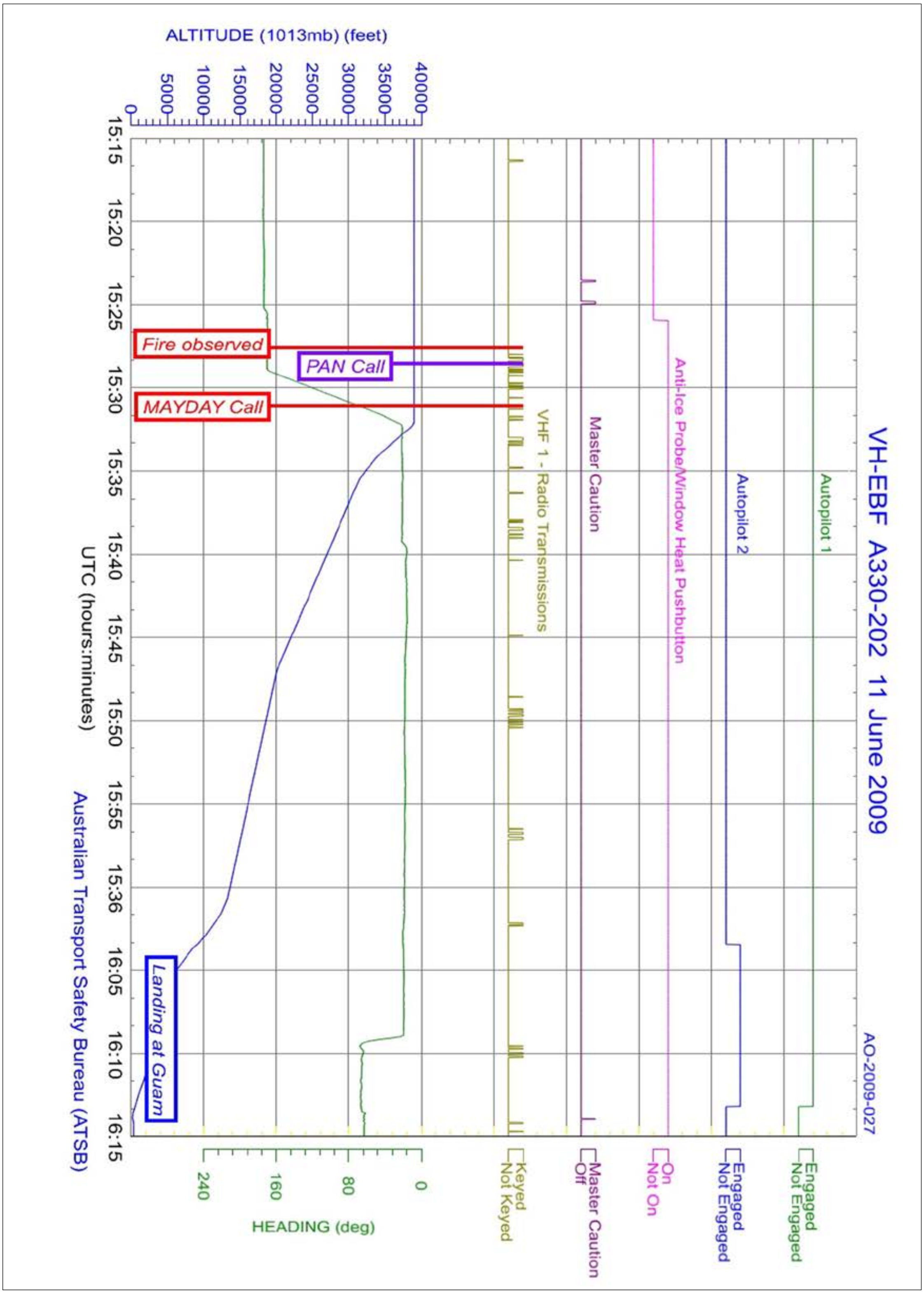
EASA have indicated to the ATSB that an Airworthiness Directive is currently being considered for release that will require all European operators of applicable Airbus aircraft to comply with the Airbus windshield replacement program (Airbus Service Bulletin A330-56-3009).

At the time of the release of this report there was no confirmed release date for the Airworthiness Directive.

## ATSB assessment of safety actions

The ATSB is satisfied that that the actions taken to date, by the various organisations will, when completed, adequately address this safety issue.

# APPENDIX A: INCIDENT FLIGHT - RELEVANT PARAMETERS FROM THE DIGITAL FLIGHT DATA RECORDER (DFDR)



# APPENDIX B: SOURCES AND SUBMISSIONS

## Sources of information

The sources of information during the investigation included:

- the flight crew of VH-EBF
- the aircraft operator
- the aircraft manufacturer and relevant component manufacturers
- the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA)
- recorded flight and other data.

## Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 25 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the flight crew of the occurrence A330 aircraft, Jetstar Airways, Qantas, the Civil Aviation Safety Authority, the French BEA, the European Aviation Safety Agency (EASA), and Airbus.

Submissions were received from Jetstar Airways, Qantas, Airbus, EASA and the French BEA. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

In-flight fire – 427 km south-west of Guam, 10 June 2009
Airbus A330-202 – VH-EBF