AVIATION OCCURRENCE REPORT

SMOKE IN THE COCKPIT

AMERICAN AIRLINES INC.

BOEING 767-223 N316AA

SYDNEY, NOVA SCOTIA 44 nm NE

12 AUGUST 1996

REPORT NUMBER A96A0146

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Summary

The Boeing 767 aircraft was in cruise flight from La Guardia Airport, New York, to Zurich, Switzerland, at flight level 370 when the crew smelled electrical smoke in the cockpit. As they donned their oxygen masks and smoke goggles, thick acrid smoke suddenly poured from behind the glareshield on the first officer's side. The smoke was accompanied by a very hot heat centre that had the appearance of an "arc welder" and by a forward equipment overheat warning. The crew declared an emergency and asked Moncton Centre the location of the nearest airport. Moncton Centre advised the crew of the location of Sydney airport; the crew initiated an emergency descent and advised the in-charge flight attendant to prepare the cabin for landing. They later informed the in-charge that they did not anticipate an emergency evacuation since, after the initial big puff of smoke, there did not appear to be any more smoke entering the cockpit. The aircraft landed at the Sydney airport without incident, with emergency response services (ERS) in position, 23 minutes after the smell of smoke was first detected. The aircraft was brought to a stop on the runway and, after ERS determined that there was no fire, the aircraft was taxied to the ramp where the passengers safely deplaned through the main cabin door in an orderly manner.

Other Factual Information

Shortly after the arcing fire and smoke started, an Engine Indication and Crew Alerting System (EICAS) message "Forward Equipment Overheat - FWD EQUIP OVHT" was annunciated. The crew then went to Standby on the equipment cooling switch as per the emergency check list; at the same time, the arcing stopped and the EICAS message also disappeared off the screen. There was no EICAS message displayed during the flight concerning the window heat and therefore no required check list item to be carried out by the crew. The smoke began to clear up, and the crew, suspecting possible fire in the forward equipment bay located under the cockpit floor, continued to descend for landing at Sydney. Electrical power to the window heat was not shut down until after the aircraft landed and the crew went through their normal shutdown procedures.

Preliminary examination of the aircraft revealed no fire or smoke damage in the forward equipment bay. However, a terminal block located on the lower outboard corner of the right (first officer's side) front windshield was extensively heat damaged and the inner glass ply of the window was cracked. The circuit breaker protection for the windshield heat had not tripped. The damage to the windshield was not readily apparent until the aircraft was more closely examined on the ground after the occurrence. The damaged windshield, the right window heat control unit, and the cockpit voice recorder were forwarded to the TSB Engineering Branch for examination and evaluation.

Interviews and a review of the cockpit voice recording revealed that there was excellent crew coordination among the flight deck crew members and between the flight deck crew and the in-charge flight attendant. The flight attendants were in the middle of meal service when the incident occurred and the captain commented on the excellent job they did of keeping the passengers calm and preparing the cabin for landing in the short time available.

The window heat control unit controls three channels for the right forward windshield and the two left-side windows. This unit has a self-test feature which displays fault messages on the EICAS; however, the unit is not equipped with electronic memory which could store any fault once power has been removed. The unit was manufactured by Garrett Canada (now Allied Signal Aerospace Canada) on 11 October 1990. The unit was further identified by part number 624066-5, series 1, serial number 100C-1815. The control unit is subject to on-conditio[1]n maintenance and, according to Allied Signal, it had never been returned to their facility for repair/overhaul since new. The control unit was tested as per "ATP Test Data Sheet 85C6865 for Window Heat Control Unit P/N 624066-3 and P/N 624066-5." The unit passed all of the test procedures except for a minor problem noted in the ramp-up voltage for the "Window 1 Control Channel Functional Tests." During the ramp-up voltage test, the voltage after 10 seconds was measured as 35 VRMS, which was slightly below the low limit of 40 VRMS. The remainder of the test values were within the prescribed limits. The lower observed value would not cause a problem with the unit's operation and requires a minor adjustment of a potentiometer to correct. The unit was considered to have been serviceable at the time of the incident.

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[1] "On condition" is defined in the Transport Canada *Airworthiness Manual* as a maintenance process having repetitive inspections or tests to determine the condition of the units, systems, or portions of structure.

The right windshield, serial number 92154H2287, was manufactured by PPG Industries Aircraft and Specialty Products in Huntsville, Alabama. The windshield is also an on-condition component; it was installed in the subject aircraft in December 1992 and, according to the aircraft records, had accumulated 14,283 hours and 2,358 cycles since installation. There was no record of any maintenance having been carried out or required on the windshield or the wiring during this time.

After initial examination at the TSB Engineering Branch, the windshield was shipped to the PPG facility in Huntsville, Alabama, for further teardown and examination. Present at this teardown were representatives of PPG, American Airlines, Boeing, and the TSB. The window and connector were further analyzed at PPG's Pittsburgh, Pennsylvania, facility at a later date.

The following summarizes the findings of the examination carried out on the window:

1. The inner glass ply exhibited melted glass and a crater-like depression directly under the location of the J5 terminal. The cracks noted in the inner ply were all directed outwards from this location. This particular glass has a melting point of 968ºC (1,800ºF).

2. The power connector originally attached to the J5 terminal was manufactured by Wallace-Black. It consists of a cadmium-plated steel insert moulded in an epoxy block with the conductor crimped into the insert. The epoxy connector was cracked but did not exhibit gross heat damage. The top of the steel insert exhibited a small, somewhat shiny buildup of material on its upper surface. The shiny area was identified as resolidified cadmium, which has a melting point of 321ºC (610ºF). No evidence of any arcing or pitting was noted on this insert. The cap over the head of the screw, the screw, and the lock washer were not recovered for examination purposes. However, a photograph taken before the windshield was removed from the aircraft shows that the cap over the head of the J5 screw was blackened and the wiring insulation was charred where it entered the connector.

3. The J5 terminal (PPG number 22-17-1385) consisted of a cast epoxy block with a threaded brass block embedded in it. The J5 terminal was extensively heat damaged and cracked. Two flat-braided copper conductors are soldered to the bottom of the brass block as installed on the window. These two braids are then routed under the glass ply and are attached to either end of a bus bar that is attached to the lower edge of the outer glass ply. There was no evidence of any copper braid remaining on the brass insert and only a small amount of solder residue was present. Microscopic examination of the brass showed it did not exhibit any pitting that may have resulted from arcing. The J5 terminal block has a cavity where the copper braids are attached to the brass block, and this cavity is filled with a polysulphide adhesive identified as PR1425. This adhesive contains carbon black as a UV stabilizer. The majority of this adhesive was either missing or had turned to ash.

4. The burned edge of the phenolic window sill was cut out, exposing the remains of approximately one-half-inch of flat, medium copper-braided conductor. Typically, there should be almost 2.5 inches of braid remaining from the edge of the inner glass ply to enable it to be soldered to the brass insert and then rotated for attachment to the edge of the window. Some of the ends of the braided copper were melted, typical of arcing damage. Copper melts at 1,080ºC (1,980ºF).

Boeing Aircraft Company reviewed its service history and found that three similar events had taken place within a year of each other from 1992 to 1993. In response to these events, Boeing sent out a "message to operators" in 1993 requiring an increase in the torque on the screws that hold the power conductors to the terminals on the windows. Maintenance personnel who removed the window from N316AA stated that the screw holding the power connector to the burned terminal was still tight.

Based upon Boeing's original concern that insufficient torque on the power lead screw might cause resistive heating, PPG conducted a test whereby a power terminal and a J5 terminal were set up in a circuit drawing 20 amperes. With the screw fully tight, a temperature increase of 10ºF (5.6ºC) above ambient (78ºF, or 25.6ºC) was recorded; when the screw was backed off until the two terminals were visibly loose, the temperature increased and stabilized at approximately 50ºF (27.8ºC) above ambient. This temperature increase is not considered significant and, based upon the maintenance personnel statement that the screw was still tight when removed from the J5 terminal, indicates that a loose screw did not initiate the overheating.

The length of copper braid brought out from the window edge is covered with heat shrink insulation. Before the braid is soldered to the terminal, this heat shrink is melted with a soldering gun and removed, exposing one-half to three-quarters of an inch of bare copper braid for soldering purposes. It is possible for the copper braid to be nicked during this operation, which would allow the strands to flex sufficiently to initiate separation. PPG had previously conducted tests using a heavy copper braid in a circuit carrying 32 amperes where they deliberately damaged the braid and measured the temperature rise. The braid was progressively cut after it had stabilized at approximately 150ºF (65.6ºC). As the braid went from 0% to 75% cut-through, the temperature increased approximately 20ºF (11.1ºC), and at 98% cut-through the temperature increased approximately 270ºF (150ºC) to 440ºF (226.7ºC). The braid used in this test was heavier than the braid used in the occurrence window, which is classified as a medium braid. It was noted that no arcing occurred during this test as the remaining copper strands carried the load, suggesting that the braids must separate for arcing to occur.

Analysis

The lack of any pitting damage on the surface of the brass block and in the remaining solder indicates that arcing did not occur at this interface. However, there was sufficient heat to melt the solder and allow the braid to completely detach from the block. The block also became sufficiently heated to melt the cadmium plate on the power terminal insert. The fact that some of the ends of the remaining copper braid in the window sill were melted is consistent with the electrical arcing observed by the pilot and strongly indicates that the arcing occurred at or near that location behind the glare shield. The high temperatures associated with arcing (thousands of degrees Centigrade) resulted in the cratering of the inner glass ply and generated sufficient thermal stresses to cause the glass windshield to crack. The temperatures associated with arcing could also vaporize copper, which may explain the loss of some of the braid.

The testing conducted by PPG indicates that the copper braid would have had to be completely separated before arcing occurred. The loss of the copper braid between the terminal and the remaining section of braid under the window edge precluded any definitive findings of what caused electrical arcing. However, it was speculated that nicking of the copper braid during construction of the window might allow the copper strands to flex sufficiently to initiate separation and allow electrical arcing to occur.

The circuit breaker for the windshield heat did not trip because there was no electrical short to ground, which would also explain the absence of an EICAS warning pertaining to the window heat system. It was not determined what caused the forward equipment overheat warning to appear on the EICAS shortly after the smoke began. However, according to Boeing and American Airlines, the EICAS message was not related to the window overheat problem.

The following Engineering Branch reports were completed:

LP 111/96 - CVR Analysis; and
LP 112/96 - Windshield Electrical Fault.

Findings

1. An electrical failure under the J5 terminal block mounted on the right front window caused localized arcing.

2. The circuit breakers for the window heat circuit did not trip nor was power removed from the system until after the aircraft landed.

3. The arcing caused cratering and localized melting of the inner glass ply, which eventually led to the cracking of the inner ply and the combustion of the epoxy terminal block, creating smoke.

4. Due to the extensive damage, the origin of the failure could not be isolated; however, it is suspected that the copper braid conductors must have severed to initiate the arcing.

Causes and Contributing Factors

An electrical failure under the J5 terminal block mounted on the right front window caused localized arcing and the combustion of the epoxy terminal block, creating smoke. Due to the extensive damage, the origin of the failure could not be isolated; however, it is suspected that the copper braid conductors must have severed to initiate the arcing.

Safety Action

Boeing informed the airline industry of this particular incident through an "In Service Action Report" which gave a brief description of the event and the findings from the teardown. Boeing also suggested that power to the window heat circuit be removed once any arcing or smoke is detected. This will prevent further heat and smoke generation, and may also allow for a more detailed analysis of the cause and origin of a failure.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 09 May 1997.