AAIB Bulletin No: 3/96 **Ref: EW/C96/1/4** **Category: 1.1**

INCIDENT

Aircraft Type and Registration:	Boeing 747-436, G-BNLA	
No & Type of Engines:	4 Rolls-Royce RB211-524G turbofan engines	
Year of Manufacture:	1989	
Date & Time (UTC):	22 January 1996 at about 0600 hrs	
Location:	Over Abbeville, France	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 18	Passengers - 341
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Fire damage in cabin, plus damage to electrical looms	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	49 years	
Commander's Flying Experience:	12,900 hours (of which 3,450 were on type) Last 90 days - Not relevant Last 28 days - Not relevant	
Information Source:	AAIB Field Investigation	

History of flight

The aircraft was on a scheduled flight from Johannesburg, South Africa to London Heathrow. At about 0600 hrs, while approaching the Abbeville VOR in the cruise at FL390, the passenger in seat 37K drew the attention of the cabin staff to 'sparks' which were coming from the floor level cabin conditioning vent, with an acrid burning smell. Two cabin crew were designated the 'fire fighter' and 'communicator'. The adjacent passengers were moved from the immediate area. One BCF extinguisher was discharged into the vent. The communicator briefed the commander and the operating first officer went back into the cabin to assess the problem. The off-duty first officer was alerted and went to the flight deck. At this stage there were no abnormal indications evident on the flight deck.

The first officer felt the cabin trim panel adjacent to seat 37K, and noted that the hottest point appeared to be about half way up. The forward edge of the panel was levered open a few inches using a crowbar and two BCF extinguishers were discharged into the gap before the panel was re-closed. After a short while the edge of the panel was raised again; no smoke or flames were visible, the smell had abated and the panel was noticeably cooler. One cabin attendant remained in the seat next to the panel to monitor the situation and another took the aisle seat to act as communicator.

The first officer returned to the flight deck and briefed the commander. A 'Pan' call was made to London ATCC at 0609 hrs. A description of the problem was passed and a priority approach to London Heathrow was requested. The aircraft was handled expeditiously and established on the localiser to Runway 09R at 0633 hrs; the surface wind was 050°/13 kt.

The aircraft landed at 0637 hrs and cleared the runway to the right. Contact with the Airport Fire Service (AFS) on 121.6 MHz was made and, as there appeared to be no immediate danger, the commander elected to continue to stand T12 and disembark the passengers in the normal manner. As the aircraft entered the stand area, shortly before the doors had been selected to manual, a member of the cabin staff reported to the flight deck that there was a smell of burning in the rest area, at the rear of the aircraft.

At 0643 hrs, the aircraft was on the stand, Door 5L was opened and fire service personnel came on board to assess the situation. They decided that there was no immediate threat and remained onboard, awaiting assistance from engineering staff before they made a more thorough inspection. The passengers began to disembark through the normal exit.

By 0700 hrs, most of the passengers had disembarked and the engineers had arrived on board. It was decided to remove the cabin trim panel and inspect the area behind it. However, as it was removed the electrical loom aft of the window suddenly emitted flames which reached up towards the overhead lockers. The first officer immediately attacked the fire with a BCF extinguisher. He then contacted the flight deck and called for all power to be switched off. The commander made a PA announcement for all non-essential personnel to leave immediately and then shut the aircraft down. The fire was rapidly extinguished and no more problems were experienced once electrical power had been removed.

Examination of aircraft

The fire had occurred in a bundle of electrical cables behind a trim panel at fuselage frame no. 1600. The cables were part of a loom, the bulk of which originated from power distribution panels P180 and P415 in the main electronic centre in the forward fuselage. The loom was routed aft, below the cabin

floor, up the cabin wall at frame 1600, and then continued aft in the cabin roof space. The size of the loom reduced along its length as cables were routed to various equipment items. A number of circuit breakers were found to have tripped on the P180 and P415 panels, in addition to two more on the P6 panel on the flight deck. Most of these were associated with the control and operation of the heaters and humidifiers in the Zone F and Door 5 crew rest areas (CRA's). One of the tripped circuit breakers on the P6 panel was ESC MISC PC ASSY (Electrical System Card file printed circuit assembly). This performed several functions, including fire detection and CRA humidifier operation.

The fire had been locally very intense, with some of the conductors having melted through, causing globules of copper to drop down towards the vent at the base of the trim panel. The loom in the cabin sidewall ran between two insulation blankets, one attached to the fuselage skin, and the other to the cabin trim panel. Both blankets were scorched and blackened. Away from the fire damaged area, it was apparent that other areas of the loom had been subjected to heat, with localised discoloration and even charring of cable insulation, and deformed and embrittled nylon cable-wraps. A photograph of the fire affected area is shown at Figure 1, with Figure 2 showing wiring loom damage remote from the fire.

The aircraft had recently been subjected to an 'Intercheck' inspection, during which many cabin windows were replaced. This involved removing the trim panels to gain access to the relevant window retention clips. The loom in the sidewall was examined carefully for evidence of electrical arcing on adjacent clips and structure that may have indicated a cable chafe, but none was found.

Using the appropriate wiring diagrams, the individual cables within the damaged loom were identified. During this process, it was noted that two circuit breakers on the P415 panel, which had not tripped, were incorrectly rated. These were 25 amp units, as opposed to the $2^1/_2$ amp circuit breakers specified in the diagram, and were fitted to the Door 5 and Zone F CRA humidifier power circuits, running off 115 volt, three phase AC, and using 22 gauge cables. Reference to the illustrated parts catalogue confirmed that the part number of the correct circuit breakers was different to those which were found on the aircraft. In fact the Zone F circuit breaker was fitted with a collar, reflecting the fact that the associated humidifier had been disabled for maintenance cost reasons.

When the P415 circuit breaker panel door was opened, it was apparent that a moderate amount of cable charring had also occurred here. It was established that all three cables from the Door 5 humidifier power relay had burned through completely. Thus power would have been present in the affected loom until such time as the final cable separated.

It was then decided to investigate the Door 5 humidifier, which was powered by a star-wound, three phase electric motor. Strip examination of the unit revealed that one of the two rotor bearings had disintegrated, with loose balls and fragments of bearing cage being distributed around the motor. Metal filings from the bearing were also in evidence and although the remaining bearing appeared intact, there was a 'notchy' feel to its operation when the rotor was turned. There was a strong acrid smell indicative of burning insulation, and it was apparent that the unit had been severely affected by heat. The resistances of the three stator windings were checked and were found to be of the order of 0.4 ohms, as opposed to 13 to 16 ohms specified in the overhaul manual. The bearing failure would most probably have been progressive, resulting in a reduction of RPM and increased current, and hence heat, in the windings. The time period during which this process occurred, or the eventual point at which the rotor ceased to rotate, could not be determined.

Humidifier control and operation

Humidifiers are connected to the aircraft's potable water system, and operate by generating an atomised water spray which is introduced into the air conditioning ducts. G-BNLA was equipped with three such units, supplying the flight deck, Zone F CRA (a row of seats at the very rear of the cabin) and Door 5 CRA (a bunk-equipped compartment located above Zone F). The controls in the Door 5 area consisted of a temperature controller and a humidifier ON-OFF switch.

A schematic of the Door 5 humidifier system is shown at Figure 3, and it can be seen from this that operating the ON switch on the control panel opens a 28 volt DC supply to a relay within the humidifier motor housing. This relay in turn controls the 115 volt, AC supply to the motor itself. However, it may be noted that the 28 volt supply is earthed, via a solid state switch within the ECS Miscellaneous printed circuit assembly. This switch is only closed under appropriate conditions as defined by a series of logic gates, thereby endowing the ECS card with a central 'enabling' function to humidifier operation.

It can be seen that conditions required for closure of the switch (ie 'enable') include "sufficient airflow" (in the air conditioning ducts) and "cruise clamp", the latter being the cruise section of the flight profile as derived from the Flight Management System (FMS). In a similar manner, the humidifier can be disabled either by "descent detect" or "two hours prior to descent" (again, read from the FMS).

The logic system also uses the various inputs to provide built-in test equipment (BITE) capability, together with fault detection functions, using databus links (via one of three interface units) with the central maintenance computer (CMC). Fault messages are stored in the CMC for later access by

maintenance personnel. Not shown on the diagram is the link into the ACARS (Airborne Communication Addressing and Reporting) system. Any system failure messages are automatically downloaded via a VHF datalink where they are stored on a computer within the airline's engineering facility.

Additional investigation

Reference to the ACARS messages that had been downloaded from the aircraft revealed two fault codes timed at 0557 hours, which was the approximate time that the fire became apparent in the cabin. The faults, which were qualified as "hard failures", were identified as a problem with the ECS Miscellaneous Card, whose circuit breaker, as noted earlier, had tripped. When electrical power was eventually restored on the aircraft, following extensive repairs to the wiring, similar fault messages were recovered from the CMC.

Both the fire and the CMC messages occurred close to the top of descent, at which time the humidifier should have been switched off for two hours, according to the operating logic. It was therefore decided to investigate the motor relay to see if the contacts had welded together, which would have kept current supplied to the motor regardless of the position of the solid state switch on the ECS card. In the event, the contacts were found in the relaxed, ie open, position. However, it was also found that a spark suppression diode, wired across the relay coil, had broken down, most probably as a result of the heat generated in the motor housing. This effectively shorted out the coil, thereby exposing the solid state switch on the ECS card to 28 volts DC, which probably caused the card failure recorded on the CMC. Visual inspection of the printed circuit assembly, which was located in a module of similar cards in the main electronic centre, revealed an area of localised burning. Subsequent investigation in the avionic workshops showed that the circuitry had suffered extensive damage, which had probably resulted from a high voltage input on three pins. Two of these were associated with separate card functions; the remaining one was the input from the motor to the solid state switch noted above. However, it was noted during the investigation that the cable which carried this signal was in the damaged loom. It was thus possible that 115 volts AC could also have been fed to the ECS card via the solid state switch.

If the operating logic had switched the humidifier off two hours prior to the top of descent, then the process of the conductor break-down within the wiring loom must have been initiated before this time, with at least two hours elapsing before the fire became apparent. The timings of the ACARS/CMC messages, and of the actual fire, suggest that the humidifier circuit was energised at least up to the top of descent. One reason for this could have been if the flight crew had significantly altered, en route, the flight plan in the FMS such that the "two hours prior to descent" cue to the ECS card was missed.

This would have invoked the "descent detect" signal to de-activate the humidifier. However, the crew made no such changes to their flight plan. Therefore, there remains a possibility of a logic error on the ECS card, either pre-existing, or perhaps occurring as a result of progressive damage in the electrical loom.

The resistance of 22 gauge cable was found to be approximately 0.15 ohms per metre. With an estimated 50 metres of cable between the circuit breaker panel and the humidifier, and adding the residual resistance of the stator coils, the total resistance per phase lead was probably around 8 ohms; this would have resulted in a current of approximately 14.5 amps. Assuming a direct short occurred in the area of the fire, the minimum resistance in the (reduced) cable run was unlikely to have been below 5 ohms, giving a current of around 23 amps. It is therefore not surprising that the 25 amp circuit breaker failed to trip. Depending on the exact value of resistance, the power consumption would have been in the region of 1.7 to 2.6 kW per phase. The heat generated as a result would not readily have dissipated in that portion of the loom behind the cabin trim panel, where it was sandwiched between layers of insulation material. This is the most probable reason for the fire breaking out in that location. Retained heat, in addition to the possibility of the humidifier supply cables shorting out on adjacent cables, were most likely responsible for the re-ignition which occurred after the aircraft landed. Elsewhere in the loom, a degree of ventilation probably prevented combustion of the cable insulation .

Finally, consideration of the other wires in the loom that had burned through did not reveal any significant airworthiness implications. Two of the tripped circuit breakers were the Systems 3 and 4 Elevator/Rudder Valves. These are motorised valves, the operation of which isolates sections of the hydraulic system for ground maintenance purposes. The flight crew later recalled seeing an advisory message concerning these valves displayed on the EICAS (Engine Indication and Crew Alerting System) screen. The message reflected the inoperable state of the valves; flying control operation would not have been affected.

Relevant aircraft history

The humidifier power circuit breakers were not serialised items, and hence there was no documentation that stated when they had been installed on the aircraft, which was constructed in 1989. However, both units bore the number 8735, which was thought to indicate the time of manufacture, ie week 35 of year 1987. The circuit breaker manufacturer was unable to determine the delivery destination of these components, as shipment records are only kept for seven years. However, British Airways stated that there was no record of the airline's stores ever having received 25 amp circuit breakers with the same part number as those found on G-BNLA.

G-BNLA was the first 400 Series aircraft delivered to British Airways and, in common with many other early aircraft, was subject to a high volume of completion and modification activity that was conducted on the flight line, as opposed to within the assembly hangars. The aircraft manufacturer assessed that the next two aircraft off the assembly line, G-BNLB and G-BNLC were completed under the same conditions and hence were vulnerable to having had the incorrect circuit breakers fitted. In fact the airline checked all their aircraft, and found that only G-BNLB had the incorrect components. Boeing stated that British Airways were the only 747-400 operator whose aircraft were delivered with the Door 5 and Zone F Crew Rest Area humidifiers, thereby confining the potential problem to this airline.

The Door 5 humidifier had been fitted to the aircraft in January 1991, since when the aircraft had flown more than 21,700 hours up to the time of the incident. The humidifiers are maintained 'on condition', although the motors have a 4000 hour 'soft' life, meaning that they are overhauled if they have exceeded 4,000 hours in service at the time of any removal. This particular unit had an early part number; the motors of later models are equipped with thermal cut-out switches. The airline found that they possessed only three other humidifiers similar to that found on G-BNLA, one on an aircraft, the others in stores. All these have now been scrapped.

FIGURE 1. View of fire damaged area (trim panel removed)

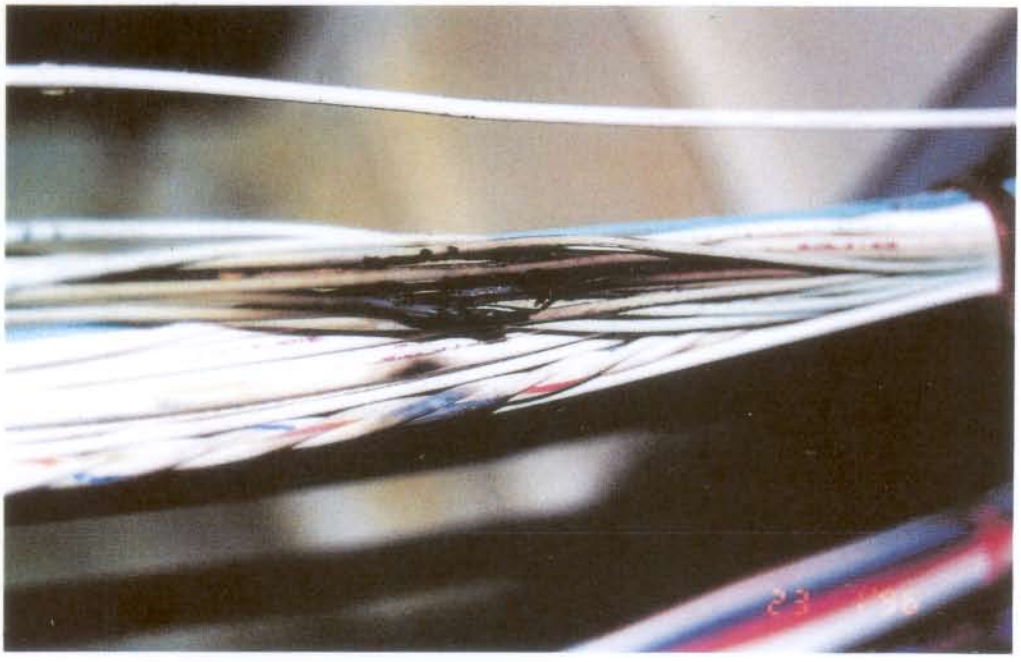

FIGURE 2. Typical damage to loom away from fire

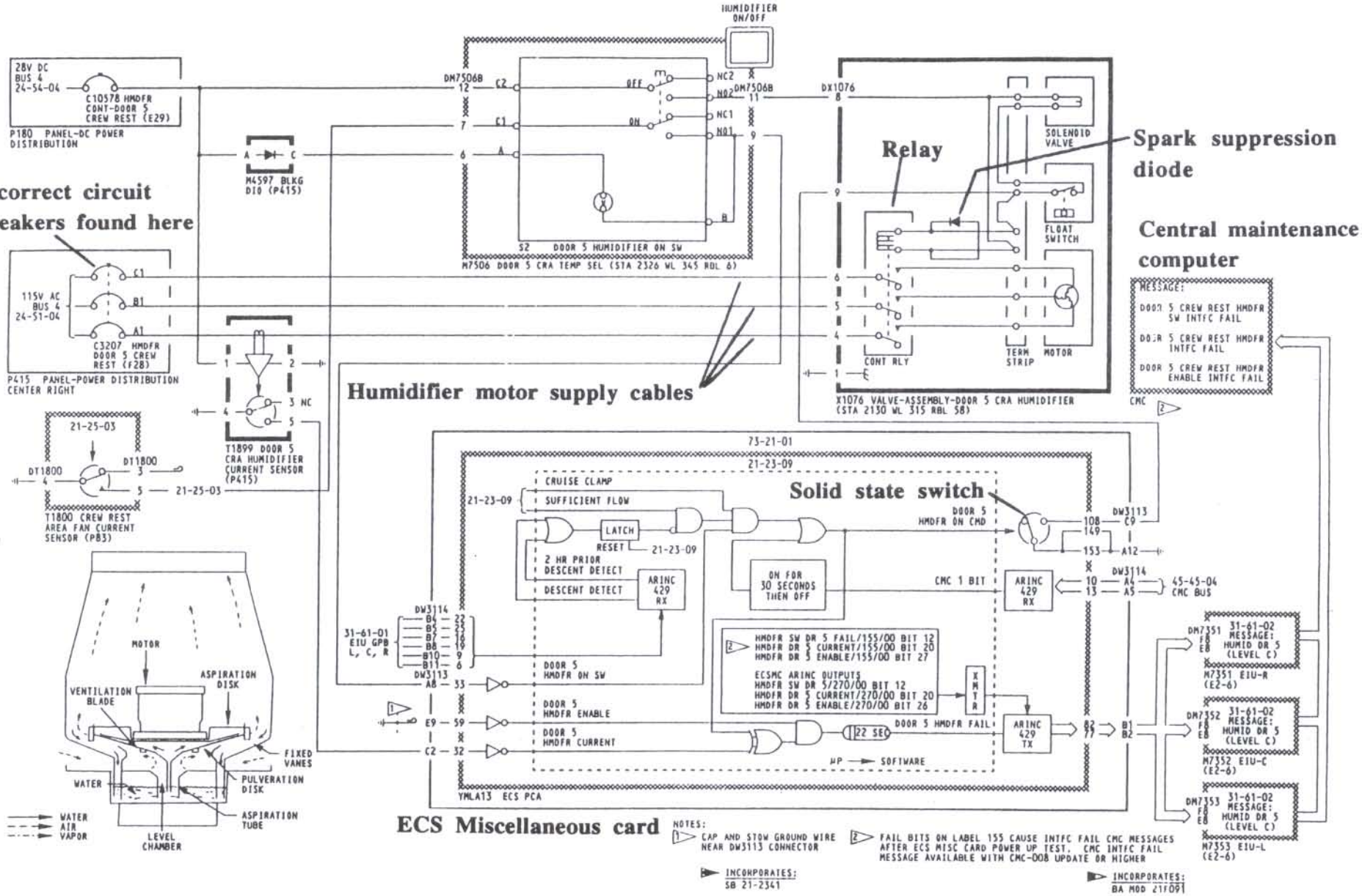

FIGURE 3. SCHEMATIC OF HUMIDIFIER OPERATING SYSTEM