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## Smoke emergency over North Atlantic, Boeing 747-436, G-BNLL, 13 April 1996

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**Micro-summary:** This Boeing 747-436 experienced a smoke emergency over the North Atlantic.

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**Event Date:** 1996-04-13 at 1200 UTC

**Investigative Body:** Aircraft Accident Investigation Board (AAIB), United Kingdom

**Investigative Body's Web Site:** <http://www.aaib.dft.gov/uk/>

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# Boeing 747-436, G-BNLL, 13 April 1996

**AAIB Bulletin No: 9/96 Ref: EW/C96/4/11 Category: 1.1**

**Aircraft Type and Registration:** Boeing 747-436, G-BNLL

**No & Type of Engines:** 4 Rolls Royce RB211-524G2-19 turbofan engines

**Year of Manufacture:** 1990

**Date & Time (UTC):** 13 April 1996 at 1200 hrs

**Location:** 2.5 hours into London to San Francisco flight

**Type of Flight:** Public Transport

**Persons on Board:** Crew - N/A Passengers - N/A

**Injuries:** Crew - None Passengers - None

**Nature of Damage:** None

**Commander's Licence:** Airline Transport Pilot's Licence

**Commander's Age:** N/A

**Commander's Flying Experience:** N/A

Approximately 2.5 hours into a flight from London to San Francisco, the flight deck filled with "hazy, acrid fumes". The 'Smoke Air Conditioning Drill' was carried out, which included the donning of flight deck oxygen masks and switching off the flight deck humidifier. However, although the fumes did not intensify, the smell remained. Accordingly, the decision was made to return to Heathrow where an uneventful landing was made.

Subsequent investigation confirmed that the flight deck humidifier unit smelt strongly of burned insulation. This unit is connected to the aircraft potable water system, and generates an atomised water spray which is introduced into the flight deck air conditioning ducts. The spray is produced by a rotating, vaned disc, which is driven by a three-phase, 115 volts AC motor. Water is drawn, via an aspiration tube, from a chamber at the base of the unit.

Before disassembly, the unit was run on a test bench, where it was found to be very noisy in operation. After stripping, it was found that the motor bearings were dry and badly worn, although they had not in fact failed. A small amount of rubbing had occurred on the rotor as a result of the worn bearings, and there was evidence of intense heat around the motor, with areas of charred insulation. The vaned disc was encrusted with heavy limescale deposits, which conceivably could have caused out-of-balance forces that contributed to bearing wear. It was also noted that additional limescale deposits had almost completely blocked the aspiration tube, thereby significantly reducing the effectiveness of the humidifier.

The records indicated that the unit had been fitted to the aircraft about 11 months earlier, and had achieved more than 4,700 flying hours.

### **Humidifier history**

Each of this operator's Boeing 747 aircraft is equipped with three humidifier units which supply the flight deck; Zone F crew rest area (a row of seats at the very rear of the cabin); and Door 5 crew rest area (a bunk-equipped compartment located above Zone F). However, due to adverse interaction between the Door 5 and Zone F humidifiers, the latter units have been permanently disabled by fitting a collar on the appropriate circuit breaker.

The humidifiers have had a reputation for unreliability, as evidenced by the airline's engineering records which indicated that 413 units were removed (across a fleet of 63 Boeing 747s) over a two year period to April 1996. Only 6 of these removals were for reasons of fitment to other aircraft. Although the records sometimes included only scant or abbreviated descriptions, there were at least 14 references to smoke/fumes on the flight deck. However it was noted that a significant number of these had "no fault found on test" entered against them. Of the remainder, many were attributed to problems with the motor. In addition, the CAA had 30 similar events on their occurrence database for the same airline, dating from August 1976.

Other problems stemming from humidifier operation have included false fire warnings. These resulted from excess moisture contaminating unsealed switchgear in the overhead panels on the flight deck. The water output from the humidifiers was reduced as a result.

In January 1996, a cabin fire occurred on a Boeing 747-436, G-BNLA, following a humidifier motor failure. In this case, the cause was a 25 amp circuit breaker which had been fitted in the associated power distribution panel in place of the specified 21/2 amp circuit breaker. The associated incident investigation was reported in AAIB Bulletin 3/96. In that incident, the humidifier was one of the very few on the airline's inventory that was not equipped with a thermal cut-out switch. These devices cut the current supply to the motor in the event that a limiting temperature is exceeded. The humidifier motor from G-BNLL was so equipped, and clearly had operated to shut down the motor before the current had risen to a level that tripped the circuit breaker. However, it would have re-set after the motor had cooled down, thus reconnecting the electrical supply. It would therefore seem that this cycling action may have resulted in prolonging the failure process and in any event, the switch had been set at a temperature level that was sufficient to prevent thermal damage, as noted at the strip examination. The engineering records indicated a consistency with regard to overheat damage.

### **Additional information**

Humidifiers are a customer specified option which equip a minority of the worldwide Boeing 747 fleet. In fact Boeing have advised that approximately 11 operators with some 16% of the Boeing 747 "classic" fleet, in addition to 13 operators with about 40% of Boeing 747-400 aircraft, have crew area humidification installed. There are no airworthiness requirements on this subject. In the UK, the CAA accept humidifiers on a "no hazard" basis. Whilst all of this operator's Boeing 747s have humidifiers, they are not fitted to any of their long-haul Boeing 767 or 777 aircraft.

Removal of the humidification system would be unpopular with aircrew, who have concerns regarding the detrimental effects of low humidity on comfort and performance. The medical effects of low humidity have been the subject of some research, and one report (Ref1) notes that the maximum additional water lost from an individual during an eight hour period in zero humidity, compared with normal day-to-day loss, is around 100 mls. The report concludes: "*The sensation of thirst experienced by a healthy individual in the low humidity environment is due to local drying of the pharyngeal membranes, and this, itself, may lead to a spurious sensation of thirst. There is no evidence that exposure to a low humidity environment ..... leads per se to dehydration.*"

Another study (Ref2) exposed two groups of eight subjects to 24 hour periods in dry (5% relative humidity) and normal (50% RH) environments. This confirmed that low humidity caused mild subjective symptoms, *ie* dryness of eyes and mucous membranes. However, there were no significant effects on reaction times or other measures of psychomotor performance, although there were some changes in fluid regulatory hormones. With regard to the latter, the report noted that: "*...this does not imply that such environmental influences (ie low humidity) are harmful and indeed, although there were relative changes in the levels of a variety of blood and urinary variables under different conditions, all values remained within the normal range. It therefore seems unlikely that low humidity has any long or short term ill effects, if overall hydration is maintained.*"

### **Safety action**

During the investigation it became apparent that the motors on some humidifiers (including the failed unit from G-BNLL) are vented into the air conditioning ducts, whilst others are sealed. The humidifier manufacturers are looking into the viability of incorporating sealed motors in all humidifiers.

The aircraft manufacturer has stated that they were aware of the problems associated with the humidifier thermal protection, and requested the vendor to redesign the system. The result was the electric motor was equipped with three thermal switches (one on each phase) of the motor windings. The trip temperature of the switches is 160°C, with a reset value of 120°C. The electric motor was successfully tested and shown not to produce smoke or fumes.

Several other (optional) improvements have been made to the humidifier: these include a larger motor upper bearing, a disc scraper installation, an improved float switch, a new shaft seal and a new bearing lubrication system. These improvements were incorporated by a production change in June 1993. The improved thermal protection was added after this date. The airline has very few of the latest standard units installed on their aircraft, with new equipment being ordered on an attrition basis. Their experience with the newer units still suggests on-going reliability problems, although not particularly associated with the thermal protection.

Since this incident, the associated smoke drills have been renamed "Smoke and Fume" drills, as many incidents have not resulted in significant quantities of visible smoke. In addition, and because of the number of associated cases of smoke on the flight deck, the following Safety Recommendation has been made to the FAA and aircraft manufacturer:

96-62: In view of the incidence of flight deck humidifier motor failures causing smoke and fumes to affect the flight decks of Boeing 747 aircraft, it is recommended that the FAA, in conjunction with the manufacturer, should require improved reliability from such units and also modification of the thermal cut-out switch on humidifiers to the latest available standard, so that this switch operates before the motor temperature rises to a level capable of burning associated cable insulation. It is additionally recommended that all thermal cut-out switches on humidifiers, and all other electric motors so equipped, should incorporate a 'latch' such that they do not automatically restart defective electric motors in flight when the temperature has reduced. The latch should only be capable of being reset on the ground, which would provide opportunity for early maintenance action to assess and replace defective units.

## References

1. RAF School of Aviation Medicine Report No 01/96

"Low humidity, dehydration, dipsosis or just dryness"

By Anthony N Nicholson

May 1996

2. Institute of Aviation Medicine Report No 705

"Physiological and psychological effects of 24 hour exposure to a low humidity environment"

By M A Stroud, A J Belyavin, E W Farmer and P J Sowood

May 1992