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

Information Source: AAIB Field Investigation

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 includedthe donning of flight deck oxygen masks and switching off theflight deck humidifier. However, although the fumes did not intensify,the smell remained. Accordingly, the decision was made to returnto Heathrow where an uneventful landing was made.

Subsequent investigation confirmed that the flight deck humidifierunit smelt strongly of burned insulation. This unit is connectedto the aircraft potable water system, and generates an atomisedwater spray which is introduced into the flight deck air conditioningducts. The spray is produced by a rotating, vaned disc, whichis 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 itwas found to be very noisy in operation. After stripping, it wasfound that the motor bearings were dry and badly worn, althoughthey had not in fact failed. A small amount of rubbing had occurredon the rotor as a result of the worn bearings, and there was evidenceof intense heat around the motor, with areas of charred insulation.The vaned disc was encrusted with heavy limescale deposits, whichconceivably could have caused out-of-balance forces that contributedto bearing wear. It was also noted that additional limescale depositshad almost completely blocked the aspiration tube, thereby significantlyreducing the effectiveness of the humidifier.

The records indicated that the unit had been fitted to the aircraftabout 11 months earlier, and had achieved more than 4,700 flyinghours.

Humidifier history

Each of this operator's Boeing 747 aircraft is equipped with threehumidifier units which supply the flight deck; Zone F crew restarea (a row of seats at the very rear of the cabin); and Door5 crew rest area (a bunk-equipped compartment located above ZoneF). However, due to adverse interaction between the Door 5 andZone F humidifiers, the latter units have been permanently disabledby fitting a collar on the appropriate circuit breaker.

The humidifiers have had a reputation for unreliability, as evidencedby the airline's engineering records which indicated that 413units were removed (across a fleet of 63 Boeing 747s) over a twoyear period to April 1996. Only 6 of these removals were for reasonsof fitment to other aircraft. Although the records sometimes includedonly scant or abbreviated descriptions, there were at least 14references to smoke/fumes on the flight deck. However it was notedthat a significant number of these had "no fault found ontest" entered against them. Of the remainder, many were attributedto problems with the motor. In addition, the CAA had 30 similarevents on their occurrence database for the same airline, datingfrom August 1976.

Other problems stemming from humidifier operation have includedfalse fire warnings. These resulted from excess moisture contaminatingunsealed 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 causewas a 25 amp circuit breaker which had been fitted in the associatedpower distribution panel in place of the specified 21/2amp circuit breaker. The associated incident investigationwas reported in AAIB Bulletin 3/96. In that incident, the humidifierwas one of the very few on the airline's inventory that was notequipped with a thermal cut-out switch. These devices cut thecurrent supply to the motor in the event that a limiting temperatureis exceeded. The humidifier motor from G-BNLL was so equipped,and clearly had operated to shut down the motor before the currenthad risen to a level that tripped the circuit breaker. However,it would have re-set after the motor had cooled down, thus reconnectingthe electrical supply. It would therefore seem that this cyclingaction may have resulted in prolonging the failure process andin any event, the switch had been set at a temperature level thatwas insufficient to prevent thermal damage, as noted at the stripexamination. The engineering records indicated a consistency withregard to overheat damage.

Additional information

Humidifiers are a customer specified option which equip a minorityof the worldwide Boeing 747 fleet. In fact Boeing have advisedthat approximately 11 operators with some 16% of the Boeing 747"classic" fleet, in addition to 13 operators with about40% of Boeing 747-400 aircraft, have crew area humidificationinstalled. 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 777aircraft.

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

Another study(Ref 2) exposed two groups ofeight subjects to 24 hour periods in dry (5% relative humidity)and normal (50% RH) environments. This confirmed that low humiditycaused mild subjective symptoms, *ie* dryness of eyes andmucous membranes. However, there were no significant effects onreaction times or other measures of psychomotor performance, althoughthere were some changes in fluid regulatory hormones. With regardto the latter, the report noted that: "*...this does notimply that such environmental influences* (*ie* low humidity)*are harmful and indeed, although there were relative changesin the levels of a variety of blood and urinary variables underdifferent conditions, all values remained within the normal range.It therefore seems unlikely that low humidity has any long orshort term ill effects, if overall hydration is maintained."*

Safety action

During the investigation it became apparent that the motors onsome humidifiers (including the failed unit from G-BNLL) are ventedinto the air conditioning ducts, whilst others are sealed. Thehumidifier manufacturers are looking into the viability of incorporatingsealed motors in all humidifiers.

The aircraft manufacturer has stated that they were aware of theproblems associated with the humidifier thermal protection, andrequested the vendor to redesign the system. The result was theelectric motor was equipped with three thermal switches (one oneach phase) of the motor windings. The trip temperature of theswitches is 160°C, with a reset value of 120°C. Theelectric motor was successfully tested and shown not to producesmoke 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 lubricationsystem. These improvements were incorporated by a production changein June 1993. The improved thermal protection was added afterthis date. The airline has very few of the latest standard unitsinstalled on their aircraft, with new equipment being orderedon an attrition basis. Their experience with the newer units stillsuggests on-going reliability problems, although not particularlyassociated with the thermal protection.

Since this incident, the associated smoke drills have been renamed"Smoke and Fume" drills, as many incidents have notresulted in significant quantities of visible smoke. In addition,and because of the number of associated cases of smoke on theflight deck, the following Safety Recommendation has been madeto 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 AviationMedicine Report No 01/96

"Low humidity,: dehydration, dipsosis or justdryness"

By Anthony N Nicholson

May 1996

2. Institute of AviationMedicine Report No 705

"Physiological and psychological effects of24 hour exposure to a low humidity environment"

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

May 1992