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Airborne Fires from damaged electrical wiring - Recent AAIB investigations and Recommendations

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Summary

The UK Air Accidents Investigation Branch has investigated a number of serious incidents involving airborne fires, resulting from damage to aircraft electrical wiring. This paper looks briefly at four such incidents, which occurred in late 2002 and early 2003, and in particular at one which occurred in a B737 aircraft in the overhead area just aft of the flight deck door. The AAIB Reports of the investigations were published in the AAIB Bulletin 6/2004 and contained a number of Safety Recommendations to the airworthiness authorities. These included Recommendations on continuing research, particularly in enhanced protection of electrical circuits.

Introduction

AAIB has been involved in a number of accident investigations, to civil and military aircraft, in recent years where the causal factors have featured electrical arcing and damage to aircraft wiring. In the civil world, the significant accidents have included the Boeing 747-131, N93119, near East Moriches, New York on July 17, 1996 (TWA 800 - NTSB/AAR-00/03) and McDonnell Douglas MD-11 HB-IWF near Peggy's Cove, Nova Scotia on 2 September 1998 (Flight 111 - Canadian Report Number A98H0003). Both these high-profile accidents were thoroughly investigated and both generated a number of Safety Recommendations from the NTSB and the Canadian TSB respectively. But there have also been a number of less publicised minor accidents and serious incidents which demonstrate that, despite greater awareness of the problems associated with aircraft wiring, these incidents continue to occur.

Four such serious incidents occurred in the United Kingdom between November 2002 and July 2003 to one airline. Because of a number of common features, the investigations were linked and when the investigation reports were published by

AAIB, in June 2004, an overview document was also published, drawing together the common features and making four generic Safety Recommendations.

The four incidents are:-

AAIB file reference	Type and registration	Date of incident
EW/C2003/06/03	Concorde, G-BOAC	13 June 2003
EW/C2003/07/07	Boeing 737-300, G-LGTI	30 July 2003
EW/C2003/05/06	Boeing 737-436, G-DOCE	30 May 2003
EW/C2002/11/02	Boeing 737-436, G-DOCH	8 November 2002

When the AAIB Bulletin was published a number of newspapers in the United Kingdom used the material to criticise heavily the particular and prominent airline involved. The view from AAIB is that, in contrast, it was the open-reporting culture of this large airline which enabled the events to be identified and the collaborative nature of their internal investigations which allowed AAIB to draw out the lessons.

A precis of these four reports follows. The full texts are available at AAIB's website, with fuller illustration.

1) Concorde, G-BOAC on 13 June 2003 - (Figure 1)

On 21 June 2003, during the routine maintenance investigation of a reported defect, a short circuit condition was detected on the Fuel Quantity Indication wiring for fuel tank No 7. Damage was found to an associated wire bundle which had been caused by a localised fire within the area enclosed by the wing/fuselage fairing area aft of the main landing gear (zone 198) below fuel tank No 3. Fuel seepage from this tank, in the area of the chafed wire, had collected in a box section fairing support member and had been ignited, resulting in a short duration, low intensity fire. The ignition source for the fire was identified as a chafed wire for the main tank No 3 fuel pump, which carries 115v AC power, arcing against the aluminium fairing.

It was possible that the chafing of this wire had been precipitated during maintenance activity two years prior to the incident when this wiring had been disturbed. The fire probably occurred during a flight from LHR to JFK on 13 June 2003, although no indications were apparent to the flight crew at that time. Modifications were introduced to prevent the build up of fuel in the box section fairing support structure and the entire fleet has since been retired from service.

That aircraft wiring deteriorates with time and, particularly, in areas subject to high levels of maintenance activity is reflected in the incident to G-BOAC. The airworthiness issues are not limited to Concorde, no longer in service, but reflect broader concerns on all aircraft types regarding wiring maintenance, particularly as aircraft age and modifications are introduced. The possibility for a wire to chafe was introduced during a maintenance input two years prior to this incident, when the wiring was last disturbed. This ultimately led to the short in-flight fuel fire.

2) Boeing 737-300, G-LGTI on 30 July 2003 - (Figure 2)

During the pre-flight preparation the crew noticed that both of the ground service circuit breakers were out, attempts to reset these were unsuccessful. The commander became aware of an electrical burning smell and smoke and asked the engineer to shut the aircraft down, ordered an evacuation and requested that the fire service be called and the aircraft was evacuated. A short duration flash fire had apparently occurred below the cockpit floor on the right side, forward of the Electrical and Electronics compartment.

Examination of the galley power feeder cables in the area showed evidence of pre-existing damage consistent with the insulation material having being torn away from the wires. The galley feeder cables carry a three phase 115V providing the possibility for arcing, and this could eventually have started the arc tracking of polyimide insulated wires. It is probable that the damage to the galley feeder cables occurred at an earlier time, possibly during the replacement of the forward toilet service panel in November 2000, over two years before this incident. It could not be determined why arcing occurred on this particular occasion.

3) Boeing 737-436, G-DOCE on 30 May 2003 - (Figure 3)

Whilst in the cruise the crew began to feel some discomfort in their ears. This was shortly followed by the cabin altitude warning horn which indicated that the cabin altitude had exceeded 10,000 feet and this was seen to continue to climb on the cockpit gauge. At the same time, the primary AUTO mode of the pressure control failed, shortly followed by the secondary STBY mode. The crew selected the first manual pressure control mode, but were unable to control the cabin altitude. An emergency descent and subsequent diversion to Lyon was carried out.

The failure of the pressurisation control system was traced to burnt electrical wiring in the area aft of the aft cargo hold. The wiring loom had been damaged by abrasion with either a p-clip or ‘zip’ strap that, over time, resulted in the conductors becoming exposed, leading to short circuits and subsequent burning of the wires. There was no other damage. The wiring for all the modes of operation of the rear outflow valve, in addition to other services, run through this loom.

Loss of the pressurisation system in G-DOCE, resulted from the abrasion of the insulation of two or more wires in the affected loom. This is a good example of a case where a loom was almost certainly damaged whilst maintenance was carried out in the area, starting the process which led to the conductors being exposed.

4) Boeing 737-436, G-DOCH on 8 November 2002 - (Figures 4 & 5)

Whilst climbing through FL240 the flight crew noticed a small amount of smoke appear on the flight deck, accompanied by a smell of electrical burning. They decided to carry out a diversion but were hampered by difficulties in communications with the cabin crew and locating the appropriate checklist, since it was not clearly identified on the index page of the QRH.

Fire damage had occurred to electrical wiring in the area of the ‘drop-down’ ceiling panel immediately aft of the flight deck door. A braided steel water supply hose to the forward galley had been attached by means of a simple electrical ‘tie-wrap’ to a wiring loom, and there was evidence of abrasion and arcing between the wires and the hose. This had resulted in the severing and shorting of a number of wires. It was determined that the hose was too long for this application and that the excess length had been looped through this overhead area and then secured by the tie-wrap to adjacent wire bundles. It was not conclusively determined when this had been done but it was most likely that the attachment was simply a short-term expedient while systems were being disconnected and disassembled, and that the error was then missed during re-assembly.

Common features

All these incidents show how vulnerable electrical wiring is to damage, occurring either due to deterioration over time or being introduced during maintenance or modification action. Periodic zonal inspections are carried out but damage and debris is often hidden within wiring bundles and is difficult to detect without disturbing the looms.

Another common feature between these serious incidents was the passage of time between the maintenance or modification activity during which the damage was done and the time of the resulting incident. This makes investigative work on the causes of the lapses more difficult, and less productive.

Regulatory activity

The main current activity amongst the regulators is the Ageing Transport Systems Rulemaking Advisory Committee (ATSRAC), an advisory committee chartered by the FAA in 1999, including members from the FAA, DoD, NASA, JAA/EASA and industry. ATSRAC's tasks covered the range of non-structural systems in ageing transport aeroplanes and their priority has been given to electrical wiring systems.

In its initial sampling work, the committee found a number of problems involving in-service aircraft types apparent from visual inspection, including deterioration of electrical wire, wire bundles, earthing leads, clamps and shielding. Items such as improper clamp sizing, inadequate clearance to structure and accumulation of dust or debris were also common. The majority of the wiring discrepancies were found to be in areas of frequent maintenance activity, or related to housekeeping.

ATSRAC identified a number of areas meriting attention and in 2002 drew up draft Advisory Circulars (ACs),

One draft FAA Advisory Circular (AC) provides guidance on changes to existing maintenance practices and analysis methods which could be applied to both in-service aircraft and new design, to ensure adequate consideration of the potential deterioration of electrical wiring systems. An important element is an enhanced zonal analysis procedure (EZAP), which has been adopted into the latest revision of the Air Transport Association of America (ATA) Maintenance Steering Group (MSG) guidelines, MSG-3. There is also information to be added to maintenance instructions designed to minimise contamination and accidental damage to electrical wiring whilst working on aircraft.

Further draft AC material provides guidance to manufacturers, operators, maintenance organisations and repair stations for developing an effective wiring systems training programme. This AC promotes the philosophy of training for all personnel who come into close proximity with wiring as part of their job and proposes tailoring of the training for each workgroup according to their needs. It also gives guidance on all essential elements of both initial and recurrent wire training programmes.

The draft ACs also give advice on developing an electrical systems standard wiring practices manual. This information is derived from maintenance, inspection, and repair best practice and promotes a common format and minimum content for documents containing standard practices for electrical wiring.

European Ageing Systems Coordination Group

In September 2003 the European Aviation Safety Agency (EASA) came into being and assumed responsibility for the certification and continued airworthiness of most aircraft manufactured and operated within the European Union. This responsibility includes continued airworthiness of all aircraft types covered by the ATSRAC work. The JAA, on behalf of EASA, started the European Ageing Systems Coordination Group (EASCG), which has the task of transcribing all the ATSRAC proposals into the European arena. It is likely that material in the FAA ACs will be adopted for use by EASA.

Discussion and AAIB Safety Recommendations

The draft ACs, generated by the ATSRAC work, address wiring standards issues of the type identified by these incidents, notably by the EZAP procedure. However, the draft ACs have not yet been published, despite draft documents having been developed and issued by ATSRAC in 2002.

As a result, the AAIB made the following Safety Recommendations:

Safety Recommendation 2004-18 - "… that the FAA accelerate publication and adoption of guidance material produced by ATSRAC …" and

Safety Recommendation 2004-19 - " … that the EASA expedite the transcription of the material in the FAA Advisory Circulars …"

Circuit breaker design

However strenuous the efforts to avoid design and maintenance quality lapses, their essentially random natures make them very difficult to eliminate. There are many reports of wiring loom damage where sustained arcing within and between looms occurred where CBs have either not operated or not operated in time to prevent serious wiring damage and, in some cases, loss of the aircraft. The four incidents reported here present such examples of sustained arcing.

Electrical circuits are protected against electrical overheating of wires by thermal/mechanical types of circuit breaker. The ‘thermal trip’ type of circuit breaker is tripped, and thus the electrical circuit broken, by heat generated within the breaker from the current in excess of its rating. This is most suitable for a ‘solid’ and continuous short-circuit but less reliable for transient arcing faults, which develop high energy over a very short period of time insufficient to trip the circuit breaker. An ‘intelligent’ circuit breaker, which could directly replace the circuit breakers presently in widespread use, can recognise the rapid current and/or voltage signature associated with arcing faults. An extensive research programme has been sponsored entirely by the FAA, and has led to the development of such arc fault circuit breakers.

The technical work of ATSRAC, and other groups operating within the regulatory framework, have been effective in advancing rapidly the technology of arc fault interrupters, particularly in reducing the size of these devices to a point where they may occupy a similar volume to their thermal forebears. As the best way to protect the existing fleet, therefore, AAIB made the following recommendations to the FAA and the EASA:

Safety Recommendation 2003-108 - “ … that the FAA expedite a requirement for the replacement of existing type circuit breakers by arc fault circuit breakers …” and

Safety Recommendation 2003-128 - “ … that the EASA expedite a requirement for the replacement of existing type circuit breakers by arc fault circuit breakers…”.

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