

Overview: Incidents resulting from damage to electrical wiring

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Introduction

A number of accident and incident reports in recent years have identified causal factors that include electrical arcing and damage to aircraft wiring. Significant accidents include a Boeing 747-131, N93119, near East Moriches, New York on July 17, 1996 (TWA 800 - NTSB/AAR-00/03), a Boeing 767-322ER N653UA at London Heathrow Airport on 9 January 1998 (AAIB/AAR 5/2000) and McDonnell Douglas MD-11 HB-IWF near Peggy's Cove, Nova Scotia on 2 September 1998 (Flight 111 - Canadian Report Number A98H0003). Ageing and maintenance related wiring incidents continue to occur despite, generally, an enhanced awareness of the problems associated with aircraft wiring systems. Four such incidents are presented together in this issue of the AAIB Bulletin; all feature damage to electrical wiring and identify similar causal factors. Although each incident may be read as a stand alone report, this overview document draws together the common issues and makes four additional Safety Recommendations. The four incidents are as follows:

EW/C2002/11/02	Boeing 737-436, G-DOCH	8 November 2002
EW/C2003/05/06	Boeing 737-436, G-DOCE	30 May 2003
EW/C2003/06/03	Concorde Type 1 V102, G-BOAC	13 June 2003
EW/C2003/07/07	Boeing 737-300, G-LGTI	30 July 2003

The Ageing Transport Systems Rulemaking Advisory Committee

Background

In 1996, the US President established the White House Commission on Aviation Safety and Security (WHCSS) which recommended that '*In co-operation with airlines and manufacturers, the FAA's ageing aircraft programme should be expanded to cover non-structural systems.*' The Commission was concerned that existing requirements, procedures, maintenance practices and inspections may not be sufficient to prevent safety related problems caused by the deterioration of aircraft systems, including wiring, as aircraft get older. The findings from this Commission formed the basis for the FAA Ageing Transport Non-Structural Systems Plan. This acknowledged that both maintenance and design issues should be investigated and, in January 1999, the FAA chartered an advisory committee, the Ageing Transport Systems Rulemaking Advisory Committee (ATSRAC), which included members from the FAA, DoD, NASA, JAA and industry. ATSRAC's primary task was '*to propose such revisions to the Federal Aviation Regulations (FAR) and associated guidance material as may be appropriate, to ensure that non-structural systems in transport airplanes are designed, maintained, and modified in a manner that ensures their continuing operational safety throughout the service life of the airplanes.*' The initial priority was given to electrical wiring systems.

Visual inspection was carried out on a number of in-service aircraft types and showed '*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. Isolated cracking of outer layers of multi-layer electrical insulation and corroded electrical connectors were also found. The majority of the wiring discrepancies were found to be in areas of frequent maintenance activity, or related to housekeeping. Fluid contamination, dust and dirt accumulations were seen on the wiring on most of the aircraft.*'

In light of these findings, a number of areas were identified as meriting attention; these included new design requirements to mitigate known problems due to ageing, which will cover wire accessibility provisions and wire selection, and wire installation to minimise strain and to provide protection from damage.

A draft FAA Advisory Circular (AC), dated 15 July 2002, was produced which 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 of this AC 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. This AC also identifies protection and caution information to be added to maintenance instructions designed to minimise contamination and accidental damage to electrical wiring whilst working on aircraft.

Another draft AC, dated 2 August 2002, 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.

A further draft AC, dated 31 October 2002, gives advice on developing an electrical systems standard wiring practices manual. The information in this AC 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.

ACs provide guidance material and the FAA proposes to publish all these ACs in the Federal Register.

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The FAA is also proposing publishing the Notice(s) of Proposed Rulemaking (NPRM), by January 2005, for the package of 'ageing systems' Rules. Existing Type Certificate holders are likely to be given 24 months after the Rule goes into effect for completion of the EZAP analyses, development of the required inspection and maintenance instructions, and their incorporation into the Instructions for Continued Airworthiness. Operators would then have a further 12 months to incorporate the required inspection and maintenance instructions into their maintenance procedures and initiate EZAP according to the enhanced maintenance programme. To ensure early attention to the three areas identified by ATSRAC as being of particular importance, ATSRAC advised the FAA to require a one-time cleaning and inspection of the cockpit, Electrical & Equipment bay, and power feeder cables within five years after the rule goes into effect. However, in order to avoid unnecessary increases in maintenance downtime, the FAA are considering not to require a one-time cleaning and inspection of these areas. Instead, these areas would receive the required attention at the appropriate periods defined by the EZAP analyses.

In further work conducted under ATSRAC, there is a general objective to develop strategies for technology transfer and implementation of the FAA research and development (R&D) products into the aviation community. The initial focus will be on Ageing Circuit Breaker recommendations and Arc Fault Circuit Breaker implementation.

European Ageing Systems Coordination Group

On 28 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, working on behalf of EASA, have recently started the European Ageing Systems Coordination Group (EASCG), which has the task of transcribing all the ATSRAC proposals into the European arena. The UK CAA chairs the EASCG, and it is highly likely that material in the FAA ACs will be adopted for use throughout the EU.

Damage to wiring

The visual inspections carried out by ATSRAC showed that aircraft wiring deteriorates with time and, particularly, in areas subject to high levels of maintenance activity. This is reflected in the incident to G-BOAC, where the airworthiness issues highlighted are not limited to Concorde, which is 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 a short duration in-flight fuel fire.

Similar factors were identified in the incident to a B737, G-DOCH, where a maintenance input led to the mis-routing of the water supply line. This resulted in abrasion between the wires and the hose, and in the shorting and severing of a number of the wires. The hose was too long for this application and the excess length had been looped through the overhead area and then secured by a tie-wrap to adjacent wire bundles. It was most likely that that this was simply a short-term expedient while systems were being disconnected and disassembled and that the 'temporary' tie-wrap was then missed during reassembly.

Loss of the pressurisation system on another B737, G-DOCE, resulted from the abrasion of the insulation of two or more wires in the affected loom. As in the other incidents, there was the possibility that the loom may have been damaged whilst maintenance was carried out in the area, and that this may have started the process which led to the conductors being exposed.

The incident to B737 G-LGTI occurred prior to flight, when the flight crew became aware of an electrical burning smell and smoke. The aircraft was shut down and the passengers evacuated. Pre-existing damage to the electrical galley feeder cables was identified which provided for the possibility of electrical arcing. It is probable that the damage to these cables occurred at an earlier time, possibly during the replacement of the forward toilet service panel.

All these incidents show how prone electrical wiring is to damage, occurring 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. The draft ACs, generated by the ATSRAC work, address wiring standards issues of the type identified by these incidents, notably by the EZAP procedure, and this has been adopted into the latest revision of MSG-3 guidelines. However, the draft ACs have not yet been published, despite draft documents having been developed and issued by ATSRAC in 2002.

Therefore the following recommendations are made:

Safety Recommendation 2004-18

It is recommended that the Federal Aviation Administration (FAA) accelerate the publication and adoption of the guidance material produced by the Ageing Transport Systems Rulemaking Advisory Committee (ATSRAC) on developing an electrical systems standard wiring practices manual, developing an effective wiring systems training programme and 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.

Safety Recommendation 2004-19

It is recommended that the European Aviation Safety (EASA) expedite the transcription by Agency the European Ageing Systems Co-ordination Group (EASCG) of the material in the FAA Advisory Circulars (ACs) produced by the Ageing Transport Systems Rulemaking Advisory Committee (ATSRAC), which gives guidance for operators and maintenance organisations on developing an electrical systems standard wiring practices manual, developing an effective wiring systems training programme and on changes to existing maintenance practices and analysis methods. This guidance

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should be applied to both in-service aircraft and new designs, to ensure adequate consideration is given to potential in-service deterioration of electrical wiring systems.

In response to this recommendation, EASA have stated that the EASCG have already drafted several documents, related to the four subject incidents, and that a meeting was scheduled for April 2004 to begin the Notice of Proposed Action (NPA) process within the EASA framework¹.

¹ NPA is similar to the Notice of Proposed Rule Making (NPRM) process followed by the FAA in the USA.

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/between looms occurred, or probably occurred, where CBs have failed to operate, or to operate in sufficient 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 findings of the ATSRAC research has shown that aircraft wiring does deteriorate with time. If wiring insulation material becomes damaged in some way, for example due to mechanical abrasion, so that the wire is exposed and a local external conductive path is available, then electrical arcing can occur. In response to previous incidents and accidents where arcing has been identified, and with regard to the development of arc-fault circuit breakers, the following recommendations are made:

Safety Recommendation 2003-108

It is recommended that the Federal Aviation Administration (FAA) expedite a requirement for the replacement of existing thermal/mechanical type circuit breakers by arc fault circuit breakers, in appropriate systems on in-service and new build Civil Air Transport aircraft for which they have issued type certificates, when these devices are judged to have been developed to an acceptable standard and where the Safety Objectives for the circuits would be enhanced.

Safety Recommendation 2003-128

It is recommended that European Aviation Safety Agency (EASA), on behalf of the member countries which have issued type certificates for Civil Air Transport aircraft, expedite a requirement for the replacement of existing thermal/mechanical type circuit breakers by arc fault circuit breakers, in appropriate systems on in-service aircraft and new build aircraft, when these devices are judged to have been developed to an acceptable standard and where the Safety Objectives for the circuits would be enhanced.