Aircraft Wiring Incidents Persist In Aging Systems

The U.K. Air Accidents Investigation Branch cited four recent incidents in which wiring problems were associated with aging aircraft electrical systems and/or maintenance issues.

FLIGHT SAFETY FOUNDATION EDITORIAL STAFF

The U.K. Air Accidents Investigation Branch (AAIB), citing several recent accidents and incidents involving electrical arcing and damaged aircraft wiring, has recommended that the U.S. Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) accelerate the distribution of guidance material for development of electrical systems standard wiring practices manuals.

"Aging [-related] and maintenance related wiring incidents continue to occur despite, generally, an enhanced awareness of the problems associated with aircraft wiring systems," AAIB said in its *Overview: Incidents Resulting From Damage to Electrical Wiring*. The overview was published along with AAIB reports on four incidents involving wiring problems that occurred between Nov. 8, 2002, and July 30, 2003.

"All these incidents show how prone electrical wiring is to damage occurring over time or being introduced during maintenance or modification action," the overview said.

Electrical Fire Disables Interphone, Cabin Lights

In the first incident, the flight crew of a Boeing 737-400 observed smoke and detected the odor of electrical burning soon after departure on Nov. 8, 2002, from London (England) Heathrow Airport for a flight to Kiev, Ukraine. Six crew members and 68 passengers were in the airplane. The cabin-call aural

warning sounded, indicating that cabin crew members were calling the flight crew on the interphone, but the captain and first officer were unable to contact the cabin crew on the interphone. They donned oxygen masks and conducted the "electrical smoke/fumes or fire" checklist.

"Both pilots were aware of continued banging on the locked cockpit door, which had commenced after their failed attempts to reply to the cabin crew on the interphone," the incident report said. "This heightened the pilots' concerns about what was happening since they were unable to either communicate with the cabin crew or establish the cause of the smoke."

After the smoke dissipated, the captain briefed the first officer and "cautiously removed his [oxygen] mask" so that he could reach the flight deck door unencumbered by the mask's hose.

"He … checked through a peephole for signs of fire or possible intruders," the report said. "Seeing neither, he opened the door and was met by a flow of water coming from a panel in the roof between the forward toilet and the galley. The cabin services director (CSD), who had been the person banging on the door, explained that about 15 minutes after takeoff, he had seen sparks and flames coming from the panel, followed shortly thereafter by a continuous stream of water."

A cabin crew member had turned off the water-isolation valve but had been unable to stop the water from pouring off the roof panel. Concerned that the water might flow into the avionics bay, the crew member then stuffed towels into the gap beneath the flight deck door. Another cabin crew member working in the rear of the airplane said that the rear galley and some cabin lights had stopped functioning.

The flight crew flew the airplane back to Heathrow where they conducted a precautionary landing, stopped the airplane on the runway and shut down the engines to allow an inspection of the airplane by aircraft rescue and fire fighting (ARFF) personnel. The visual inspection revealed no fire or damage, and thermal imaging revealed no hot areas in the airplane's ceiling; nevertheless, the report said, "on pulling down the damaged ceiling panel [just outside the flight deck door], a [burned] wiring loom [bundle of wires] could be seen. Next to this was the water-supply hose to the forward galley, from which water was still pouring."

The investigation found that damage

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had occurred in an area inside the ceiling panel where a braided-steel hose (a water hose that delivered water from the crown of the fuselage to the galley on the right side of the forward cabin) had been secured with a nylon electrical tie-wrap strap.

The report said, "It appeared that there had been abrasion and arcing between the wires and the hose, resulting in the severing and shorting of a number of the wires. The braided-steel hose was lying against the frame of the ceiling panel, and it appeared that there had also been electrical shorting to this portion of the airframe."

In one section of the hose, the steel braid had melted, and at least two holes had formed in the inner hose, resulting in the water leak.

"Comparison with a sister aircraft … indicated that the hose was too long for this application and that the extra length … had been looped through this overhead area and then only secured by a tie-wrap to adjacent wire bundles," the report said. "Part of the hose was protected by plastic spiral wrap, but this did not extend to the portion of the hose in contact with the wire bundles."

Twenty-five circuit breakers were activated (tripped) during the incident, including those that provided the cabin interphone and cabin lighting.

The report identified three principal causal factors of the incident:

• "The excessive length of the steel-braided water hose to the forward galley;

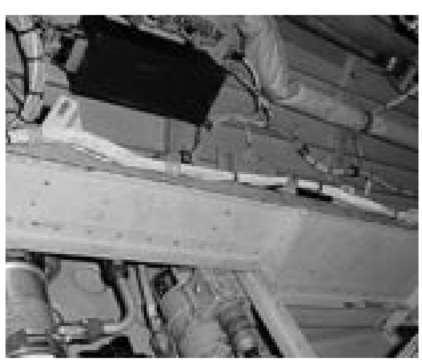
• "The lack of an established routing or restraint of this extra hose; and,

• "The unexplained securing of this hose to the electrical loom."

Investigators were unable to determine when or how the hose was attached to the electrical loom, but the report said, "It is most likely that it occurred during the period of maintenance [from June 29, 2002, to Aug. 15, 2002] and that the attachment was simply a short-term expedient while systems were being disconnected and disassembled and that the 'temporary' tie-wrap was then missed during reassembly.

"In each of these three cases (excessive length, informal routing, inappropriate securing), the hazard created was inadvertent, and in each case, there existed, in principle, a procedure to avoid this type of hazard. In principle, the interface documents between the airframe manufacturer and the suppliers of customer-specified equipment (such as galleys) should have prevented the … galley [from] being supplied with a hose of excessive length. In principle, the quality processes of the maintenance organization should have identified the hazard consistently posed by the excessive hose length and the lack of routing or restraint; the same quality processes should, in principle, have prevented the securing of the water hose to the electrical loom and [should have] identified the hazard after it occurred.

"However strenuous the efforts to avoid these design and maintenance quality lapses, their essentially random natures make them very difficult to eliminate. This has been apparent in the AAIB investigations of a number of recent accidents and serious incidents where a range of circumstances have led to electrical arcing failures, where conventional circuit breakers have not tripped."



Based on the findings of the incident investigation, AAIB recommended that Boeing Commercial Airplanes review the section of the maintenance manual that provides information about the installation of the forward galley in the B-737-400 and other affected models "to give clear instruction as to where the galley water-supply hose disconnection should be made when removing the galley" for maintenance.

In response, Boeing said that maintenance manual instructions are "often generic in nature for this type of application" because of the variety of galley installations in B-737s. (For example, the operator of the incident airplane had B-737s with six different galley installations.) Nevertheless, Boeing said that its representatives would review the hose installation "to ensure the security of the extra length of hose and validate any necessary changes to the galley installation and/or its procedures;" the review was to include "necessary specific instructions for securing the extra length of hose, or [development of] alternative solutions."

Wiring Failure Cited in Depressurization Incident

In the second incident, a B-737-400 was in cruise flight near Lyon, France, en route from Marseille, France, to London Gatwick Airport, on May 30, 2003, when the cabin-altitude warning horn sounded, indicating that cabin altitude had exceeded 10,000 feet. The pressurization control panel indicated that cabin altitude was increasing. Both the primary pressurization control system and the secondary pressurization control system failed, and the flight crew was unable to control the cabin altitude using the manual pressure-control mode. The crew conducted an emergency descent to establish a cabin altitude below 10,000 feet and diverted to Lyon. Seven of the 128 passengers received minor injuries (ear problems and/or sinus problems) as a result of the depressurization.

A preliminary inspection of the airplane showed that no circuit breakers had been activated during the incident, that the rear outflow valve (OFV) could be operated in the standby mode and in one of the manual control modes but not in the primary mode or the first manual control mode, and that the OFV-position indication on the flight deck was incorrect. During a ferry flight to Gatwich, the circuit breaker for the aft drainmast heater was activated twice.

The investigation revealed that the depressurization incident resulted from a wiring failure in a loom at the rear of the aft cargo hold.

"The wiring loom had been damaged by abrasion … that, over time, resulted in the conductors becoming exposed, leading to short circuits and subsequent burning of the wires," the report said. "The wiring for all the modes of operation of the [OFV], in addition to other services, [runs] through this loom."

The report said that the short circuits probably "allowed erroneous signals to be sent to the OFV, causing it to start to open, thus increasing the cabin altitude."

Insulation-blanket material was found in the over-pressure relief valve—an indication that the valve had operated sometime in the past to prevent excessive pressure in the fuselage.

The report said that this incident was an example of "the problem of routing the wiring for redundant systems—in this case, the primary … and secondary [standby] systems for control of the aircraft's pressurization—in the same loom. This defeats the object of having such alternative systems, should a single-point failure of the wiring loom occur.

"… Had the wiring for the [primary] and [standby] pressurization mode commands and the position feedback wire to the OFV been suitably separated, then it is less likely that the failure of one loom would have resulted in the effective failure of all control modes."

AAIB recommended that Boeing consider "separating or protecting the wiring associated with the different modes of operation of this system, which connects the cabin pressure controller to the [OFV], such that any single-point failure of the loom would not result in effective failure of the pressurization-control system."

Chafed Wire Ignites In-flight Fuel Fire

In the third incident, a routine maintenance investigation of a reported defect resulted in the discovery on June 21, 2003, of a short circuit of the fuel-quantity-indication system wiring for fuel tank No. 7 on a Concorde. Maintenance personnel also found fire damage to an associated wire bundle in the wing/fuselage fairing area behind the main landing gear and below fuel tank No. 3. The report said that "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 report said that the fire probably occurred during a flight June 13, 2003, from Heathrow to John F. Kennedy International Airport (JFK) in New York, N.Y., with nine crew members and 98 passengers aboard the airplane. The flight crew received no indication of a fire during the flight. There had, however, been intermittent displays of "failure flags" for several of the Concorde's fuel tanks and for the center of gravity (CG) computer; the report said that the gauges did not actually fail during the flight and that the indications on the CG computer appeared to be near the calculated value.

"The ignition source for the fire was identified as a chafed wire for the main-tank No. 3 fuel pump, which carries 115 [volts alternating current] power, arcing against the aluminum fairing," the report said. "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 [Heathrow] to JFK on June 13, 2003, although no indications were apparent to the flight crew at that time."

After the incident, action was taken to prevent fuel accumulation in the area where the fire occurred.

The investigation found that the wiring in the area of the fire had been installed during manufacture of the airplane in 1975. In 2001, during maintenance to repair structural cracks, "it was necessary to disturb the wiring," the report said.

"It is likely that in reinstating the wiring, the possibility for the chafe to occur was introduced. This area is not routinely inspected, and given the low number of hours flown by each aircraft, [the area] is unlikely to have been inspected within the period since the repair."

Damaged Feeder Cables Cited in Preflight Fire

In the fourth incident, the six-member crew of a B-737-300 was preparing for departure from Newcastle Airport, Tyne and Wear, England, on July 30, 2003, when they observed that both ground-service circuit breakers had been activated and tried unsuccessfully to reset them.

"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," the report said. "A short-duration flash fire had apparently occurred below the cockpit floor on the right side, forward of the electrical and electronics compartment."

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An examination of galley-power-feeder cables revealed pre-existing damage "consistent with the insulation material having been torn away from the wires," the report said.

The report said that the galley-power-feeder cables probably were damaged earlier, possibly when the forward toilet service panel was replaced in November 2002, and that investigators could not determine why arcing occurred on this occasion.

Quick Development of Guidelines Recommended

The overview said that visual inspections conducted by the Aging Transport Systems Rulemaking Advisory Committee (ATSRAC), established by FAA in 1999 and also including members from the European Joint Aviation Authorities (JAA), the U.S. Department of Defense and the U.S. National Aeronautics and Space Administration, found that aircraft wiring—especially wiring located in areas that are subject to frequent maintenance—deteriorates over time.[1]

In developing recommendations for changes in U.S. Federal Aviation Regulations and related guidance material concerning aging aircraft, ATSRAC emphasized electrical wiring systems, and FAA in 2002 prepared three draft advisory circulars to provide guidance on changes in existing maintenance practices and analysis methods to ensure adequate consideration of the potential for the deterioration of electrical wiring systems, to provide guidance for developing an effective wiring systems training program and to provide guidance on developing an electrical systems standard wiring practices manual.

FAA has proposed publication in January 2005 of a notice of proposed rulemaking on aging aircraft systems.

The AAIB overview recommended that FAA "accelerate the publication and adoption of the guidance material produced by...ATSRAC on developing an electrical systems standard wiring practices manual, developing an effective wiring systems training program 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."

JAA has established the European Aging Systems Coordination Group (EASCG) to develop the ATSRAC proposals for use in the European Union.

The AAIB overview recommended that the European Aviation Safety Agency (EASA) "expedite the transcription [by EASCG] of the material in the FAA advisory circulars … which gives guidance for operators and maintenance organizations on developing an electrical systems standard wiring practices manual, [on] developing an effective wiring systems training program and on changes to existing maintenance practices and analysis methods. This guidance 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 the recommendation, EASA said that EASCG had drafted several documents and was beginning its "notice of proposed action" process.

AAIB Recommends Improved Circuit Breakers

The AAIB overview said that numerous incidents and accidents have occurred in situations in which circuit breakers either failed to operate or did not operate in sufficient time to prevent serious wiring damage.

"Electrical circuits are protected against electrical overheating of wires by thermal/mechanical types of circuit breaker." The report said. "The 'thermal trip' type of circuit breaker is tripped, and thus the electrical circuit [is] broken, by heat generated within the [circuit] 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 recognize the rapid current and/or voltage signature associated with arcing faults."

FAA research has led to the development of these "arc-fault" circuit breakers, and the AAIB overview recommended that 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."

The AAIB overview also recommended that 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." ❑

[Flight Safety Foundation editorial note: This article, except where specifically noted, is based on Letter From the Chief Inspector of Air Accidents (one page); Overview: Incidents Resulting From Damage to Electrical Wiring (seven pages); and four accompanying aircraft incident reports – EW/C2002/11/02 (18 pages with illustrations), EW/C2003/05/06 (seven pages with an illustration), EW/C2003/06/03 (six pages with illustrations) and EW/C2003/07/07 (five pages with illustrations. The documents were published in the June 2004 AAIB Bulletin.]

Note 1. The Aging Transport Systems Rulemaking Advisory Committee (ATSRAC) said that its visual inspections of aircraft showed "deterioration of electrical wire, wire bundles, earthing [grounding] 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."