NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

October 7, 1999

SYSTEMS GROUP CHAIRMAN FACTUAL REPORT ADDENDUM FOR ELECTRICAL SHORT CIRCUIT/ARCING OF AGED AIRCRAFT WIRING

A. ACCIDENT: DCA96MA070

Location : East Moriches, New York

Date : July 17, 1996

Time : 2031 Eastern Daylight Time

Airplane : Boeing 747-131, N93119
Operated as Trans World Airlines (TWA) Flight 800

B. SYSTEMS GROUP

Chairman : Robert L. Swaim
National Transportation Safety Board
Washington, D.C.

C. SUMMARY

On July 17, 1996, at 2031 EDT, a Boeing 747-131, N93119, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK) All 230 people aboard were killed. The airplane was being operated as a Code of Federal Regulations (CFR) Part 121 flight to Charles De Gaulle International Airport (CDG) at Paris, France, as Trans World Airlines (TWA) Flight 800. Wreckage from the airplane was recovered from more than nine square miles of ocean. Reconstruction of portions of the wreckage found evidence of an explosion in the center wing fuel tank (CWT)

The Systems Group examined wiring in 16 transport category airplanes from February 21 through 25, 1998. (See the Group Chairman Factual Report Addendum for Wire Inspections, dated July 28, 1999). The group found damage to wire insulation, fluid stains on wires, and metal shavings resting on and between wires in wire bundles. As a result of these findings, the Safety Board contracted Lectromechanical Design Company (Lectromec) to conduct laboratory research of short circuit properties with BMS13-42 and BMS13-42A wires from a retired Boeing 747 and with MIL-W-81381 wire (as a baseline). The conductive materials used in tests were metal shavings, water, and lavatory fluids. Lectromec found three categories of electrical activity that were characterized as scintillations, flashing, and strong arcing. Lectromec also performed abrasion tests to examine how metal shavings damaged wire insulation. Lectromec Report No. N191-RPT4AU99 is attached.

Robert L. Swaim
TWA 800 Systems Group Chairman

10/7/99

Electrical Arcing of Aged Aircraft Wire

for the

National Transportation Safety Board

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Robert Swaim,
Chairman, TWA800 Systems Group

performed under
Order No. NTSB18-99-SP0127

Report No. N191-RPT4AU99

by
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Report Date: August 4, 1999
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EXECUTIVE SUMMARY

This report describes the results of several different tests relating to the short circuit properties of aged wires. The two types of wire insulations were crosslinked aliphatic polyimide-insulated (BMS13-42 and BMS13-42A) wire and a tape-wrapped aromatic polyimide (MIL-W-81381). The BMS wire had been removed from a Boeing 747 airplane (N93117) that had been in service for more than 25 years. The MIL-W-81381 was used for comparison and a baseline to existing data.

The following four types of tests were conducted:

Wet short-circuit between conductors with a 1% saline-water electrolyte solution, conducted to SAE test standard AS4373 4.5.9 Method 509 (with deviations) for up to 25 minutes.
Wet short-circuit between conductors with lavatory fluid taken from an airplane.
Abrasion tests that placed metal shavings between oscillating wires.
Short circuit tests using metal shavings as the conductor.

There were three different categories of electrical activity observed during the arcing experiments. Each of these activities had unique visual and oscillograph signatures.

Scintillations: high frequency, micro-discharges which causes formation of char on the wire over time.
Flashing: an arcing discharge which can continue over several cycles but not 100s of cycles. Typically 2 to 4 joules of electrical energy are transfer between source and target wire but in some cases up to 90 joules were transferred. Flashing will not cause circuit breakers to open (trip) but will erode the conductors over time.
Strong arcing: an arcing discharge that continues over 100s of cycle and often ends with interruption of power due to the circuit breaker tripping. Typically 5 kilojoules of electrical energy were dissipated in strong arcing events

Strong arcing was not associated with W42A/8/1-20 wire, but was found in 1 of 3 tests that used W42/1/1-20 wire, which has a thinner layer of insulation. Strong arcing always resulted during wet testing of MIL-W-81381.

Half-sections of aluminum tube were placed behind the wet tests to provide a backdrop for video-recording and to capture material ejected by the short circuit event. Flashing and arcing were normally directional, not a ball-shaped discharge. The direction of the discharge was normally away from the side of the wire bundle that the wires were on and the discharge of some tests did not hit the aluminum tube sections.

More than one type of abrasion test was performed to examine how metal shavings damaged BMS13-42 and BMS13-42A (no MIL-W-81381) wire insulation. The metal shavings

were placed between wires in small bundles, as found during Safety Board tests of February 21-25, 1998, and the bundles were moved with an oscillating bar. The results depended on differences in how the bundles were moved and the size of the shavings. In one configuration two of four (50%) tests resulted in the metal shaving exposing the conductor. In a second configuration, neither of two (0%) tests resulted in the shavings exposing the conductor. However during these tests three separate wires had cracks appear in the insulation due to the ½ inch oscillatory flexing after about 19 hours

Tests were conducted to document the short-circuit capability of the metal shavings on wires that already had the conductor exposed. In five of eight (62.5%) of the tests, the metal shaving acted as a fusible link, interrupting the short-circuit without causing additional damage to the insulation. In the other three tests (37.5%) damage was done to the adjacent wires during the flash event, but in no case did strong arcing occur.

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Background

Arc tracking of aircraft wire is an issue that has received attention in the past[1,2] because of the potential for equipment malfunction and because it can be a safety risk. There now are common standards for testing different aspects of arcing in qualification tests for new wire.

One of these aspects is the wet arc tracking of the wire. On aircraft, liquids do get onto wires for a variety of reasons: spilled beverages, leaking lavatory water, condensation, or moisture absorbed into salt or other surface contaminates. This can lead to carbon tracking which is a process where a conducting carbon path is slowly built up over time due to low level electrical discharges on the surface of the wire. Figure 1 shows an example of carbon build up on 81381 type wires. This carbon build up can lead to arcing.

Another potential issue is metal drill shaving on and in wire bundles and the potential for mechanical damage to the insulation. The Safety Board investigation documented numerous cases of metal shavings on wire bundles and between the wires of bundles. Figure 2 shows an example of this.

1. F. C. Campbell, Flashover Failures from Wet-Wire Arcing and Tracking, NRL Memorandum Report 5508, pg. 1, Naval Research Laboratory, Washington, DC, (1984)

2. P. L Cahill and J. H. Dailey, Aircraft Electrical Wet-Wire Arc Tracking, Report No. DOT/FAA/CT-88/4, FAA Technical Center, Atlantic City, NJ, (1988)