747 Fuel Probe Evaluation--A/C N93119
TWA Flight 800
(Failure Analysis)

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Evaluation Report
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PURPOSE

Examine and provide factual data on submitted fuel quantity measurement components from TWA 800 mishap wreckage (aircraft N93119). These parts were specifically examined for arcing, burning, or other anomalies.

BACKGROUND

The National Transportation Safety Board (NTSB) requested analysis of fuel probes, compensators, and wiring removed from 747 aircraft N93119 wreckage. Submitted hardware was removed from the ocean and had been identified, inspected, and tagged by investigators. The parts received were reported to be from the center and wing fuel tanks of the mishap aircraft. Before delivery to WL/MLSA, the parts had been stored in a warehouse. WL/MLSA was requested to examine probe components for evidence of arcing, electrical shorting, or build-up of low resistance paths (due to residue films) that could degrade probe system electrical properties. The request was made at a meeting with the NTSB subsystem accident board on June 1997. The method of analysis used was to optically inspect components, photograph areas of interest, chemically identify materials and residues or contamination of interest, and only conduct a destructive analysis when warranted. In support of this investigation, intact 747 aircraft center tank fuel probes from retired aircraft N17105 were also provided for analysis. A complete analysis on these fuel probes is given in Appendix A.

FACTUAL DATA

After documenting the initial condition of all materials submitted for evaluation, each sample was visually inspected. Samples of the materials used to construct the probes, compensators, and associated ship's wiring were collected and sent for chemical analysis. Refer to Appendix B for the chemical analysis data referenced in this report. Examples of the fuel probes submitted for analysis from N93119 are given in Figures 1 and 2.

As reported, the N93119 probes, compensators, and associated wiring were heavily damaged during the mishap and were recovered from the ocean floor. Many samples had surface residues, present in trace amounts, which, when analyzed, were found to most closely match references for aluminum (Al), silicon (Si), sulfur (S), potassium (K), chlorine (Cl), and calcium (Ca). Many samples also had gray, granular deposits that closely matched references for silicate type minerals. This combination of residues and deposits is consistent with immersion in seawater.

The following is a summary of chemical analysis results. Unless otherwise noted, a microscope equipped Fourier transform infrared spectrometry (FTIR) system was used to chemically identify materials. This system identifies materials by producing spectra that can be matched with known reference materials.

The outer tube of the fuel probes most closely matched FTIR references for an anodized aluminum alloy. Using X-ray fluorescence (XRF) and quantitative analysis by means of inductively coupled plasma-optical emission spectrometry (IPC), the alloy was found to closely match 6061 aluminum

The center tube material most closely matched FTIR references for nickel with traces of cobalt and iron. The finish material most closely matched FTIR references for a polyurethane type coating.

Plastic spacers, used to maintain proper spacing and to electrically isolate the inner and outer tubes were analyzed. They most closely matched FTIR references for polytetrafluoroethylene (PTFE), also known by the trade name Teflon®.

The terminal blocks were found to be composed of material closely matching FTIR references for an isophthalic acid based polyester with a kaolinite type silicate filler.

Probe wiring at the terminal blocks consisted of shielded white insulated Hi-Z wires, unshielded red insulated Lo-Z wires, and unshielded black insulated pigtail lead wires. The black pigtails were used to connect the Hi-Z shields together (Figures 3 and 4). Depending on the probe location or type, more than one wire was connected to the terminals. X-ray fluorescence (XRF) was used to determine that the stranded conductors of both shielded and unshielded wires had silver-plated copper conductorS. All conductors were found to be 20-gauge, by means of strand count and measured diameter. XRF was used to determine that the stranded shield braid base metal was silver-plated copper. All wire insulation, including both inner and outer layers on shielded wire, closely matched FTIR references for PTFE.

The black pigtail wires were soldered to the shield braid and insulated with heat shrink tubing (Figure 5).

The Lo-Z, Hi-Z, and shield pigtail wires were terminated with crimp-on ring terminals that were mounted on threaded posts on the terminal block. The ring terminals were held in place with a nut tightened onto the threaded terminal posts (Figure 6).

Due to extensive post mishap damage no electrical measurements were taken of the wiring, fuel probes, or compensators from N93119.

Prior studies by WL/MLSA have found semiconducting copper sulfide and silver sulfide residues on aircraft fuel probe wiring and termination areas. These films typically have a gray/black/tan color, depending on composition and thickness. These findings are documented in reports previously released to the NTSB. Areas on fuel probe components that appeared to be discolored were closely inspected and photographed. Particular attention was paid to samples determined to be from the center tank. These samples were submitted for chemical analysis to determine if the discoloration was due to interaction with fuel or exposure to high temperatures characteristic of electrical arcing or a short circuit. Residues or discoloration areas were found on wire insulation, probe elements, and on or near, wire termination areas (Figures 7 through 15). Some of these areas were examined using a scanning electron microscope (SEM) with energy dispersive spectrometry (EDS). This analysis identified high concentrations of copper, silver, and sulfur in the residue areas when compared to areas without residues. Figures 12 and 13 show a damage site with concentrations of silver, copper, and sulfur residues on the surface of the insulation. Figures 14 and 15 show a very similar site, but no residues were visible on the insulation, and none were detected with EDS. Isolated discolored areas found on probe elements were characteristic of thermally degraded polyurethane (Figures 16 and 17). No melting of metallic parts or arc tracking on the surface of insulators was noted.

All wiring insulation associated with the fuel probe terminal blocks was inspected for damage or degradation that might have been present before the mishap. Typical damage associated with the mishap event is shown in Figures 18, 19, and 20. Inspection revealed several insulation damage areas on the wiring that would be more characteristic of long-term mechanical loading from the center tank and other areas. PTFE deformation can be seen in Figures 21 through 24. Similar deformation was seen in N17105 fuel system wiring where wires were tightly pressed together, pressed against the terminal block, or compressed inside the strain relief clamp. Such sites showed evidence of thinning where the insulation was compressed and deformed. Conductors were either exposed or could be seen through the remaining thin insulation covering. Appendix A shows additional examples from aircraft N11705 of insulation damage characteristic of long-term mechanical loading.

A Hi-Z shield pigtail lead wire on fuel probe sample #31 from N93119 was found to significantly deviate in construction from all other N17105 and N93119 shield pigtails. The lead was found attached at one end, by means of the usual crimp-on ring connector, to the shield terminal post (Figure 25). The other end of this lead had been separated from the Hi-Z shield. The loose end of the wire was wrapped in what was identified as PTFE tape and tied with nylon cable lacing material (Figures 26 and 27). When the tape was removed, a crimp-on butt connector was found (Figure 28). The pigtail lead was crimped into one end of the connector and the wire crimped into the other was **braid** from Hi-Z conductor shielding. The strand diameter, base metal, and plating material all closely matched samples of shielding braid. The shielding was formed into a lead wire for crimping by gathering and twisting a length of unbraided strands. This twisted end was then apparently doubled over and placed in the remaining end of the butt connector and crimped. The joint and twisted shielding were wrapped with Teflon® material. An adhesive was used to hold the wrap together.

The braid side of the joint was found to have been shredded away from rest of the Hi-Z wire shielding. The individual braid strand fractures were inspected in an SEM. Inspection revealed that some strands exhibited necking and ductile dimples characteristic of overload failure (Figure 29). Others had a flat and angled surface more characteristic of a fatigue failure mechanism. The flat fractures were severely corroded (Figure 30).

SUMMARY OF DATA

PTFE insulation displacement and mechanical damage were noted on several wires associated with fuel probe terminal blocks. Several of the damaged wires exhibited characteristics of long-term mechanical loading or cold flow. PTFE materials are susceptible to cold flow or creep when subjected to continuous mechanical loading in compression. This type of damage was noted on the Lo-Z, Hi-Z, and Hi-Z shield pigtail wires. It was primarily found where the wires came in contact with, or were compressed by, the strain relief clamp. Other damage sites were found where wires were wrapped tightly together, placing the insulation of each wire in compression against the other.

No evidence of arcing or electrical shorting was found on the examined fuel probe components.

Residues on fuel probe wire terminations and terminal blocks were similar to residues found in previous WL/MLSA fuel probe investigations. Probes and compensators from retired 747 aircraft, N17105, had matching residue deposits. The residues consisted of copper, silver, and sulfur. High concentrations of silver, copper, and sulfur, seen in N17105 samples adjacent to conductors exposed due to compression damage, were not as evident on N93119 wiring. While the sulfide films are insoluble in water, they may be washed off by the rinsing action of moving water. A secondary reason is related to where mechanical stresses were concentrated on the wiring. Sites where premishap compression damage was most likely to be found also tended to be where substantial amounts of mishap induced damage occurred.

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