Analysis of Hot Stamped Wiring
(Failure Analysis)

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Evaluation Report
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As is usual for this type of investigation the efforts of others are critical to its success. The author would like to thank Mr. John Ziegenhagen and Mr. Richard Reibel of the University of Dayton Research Institute for expert photography.

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Analysis of Hot Stamped Wiring

PURPOSE

Examine submitted wire for electrical or mechanical damage.

FACTUAL DATA

The National Transportation Safety Board (NTSB) requested analysis of a scavenge pump relay with an attached connector and wire bundle removed from 747 aircraft N93119 wreckage (Figure 1). Submitted hardware was removed from the ocean and had been identified, inspected, and tagged by investigators. Findings concerning the relay are given in evaluation report WL/MLS 97-86. The connector wiring portion was inspected and the wire markings had deeply penetrated the insulation (Figure 2). These marks were consistent with a hot stamp marking process. For comparison purposes a hot stamp marked wire in 1997 is shown next to a relay wire in Figure 3.

The relay wiring was reported to be 20-gauge BMS 1342A (Poly-X) insulation. Two markings were noted. One was marked using ink and consistent on all wires (W42/1/1/20). The other was hot stamped and different for each wire (as an example: W 74-Q-06) In at least one location, a crack was noted in a hot stamp mark (Figure 4). Inspection with an optical microscope revealed the conductor was exposed. Exposed conductors were always associated with a crack. There was no evidence of arc tracking or thermal degradation from sustained current flow.

Sections of four wires were removed from the relay connector and cross sectioned to ascertain the depth of the hot stamp marks. Perpendicular and lateral cross sections are shown in Figures 5, 6, 7, and 8. The multiple insulation layers can be seen clearly in Figures 5 and 6. Three wrapped layers (white, amber, and semitransparent) were noted. An average thickness of each layer is given in Figure 5. The average total insulation thickness was 201 um (Figure 5). Considerable thickness variability was noted in the inner white layer (Figures 5 and 6). Also note deformation in the inner layer at the mark sites in Figures 5 and 6. The insulation thickness was significantly reduced in the marked areas (Figures 5 and 6).

Figures 7 and 8 show the uneven mark depth in the lateral cross sections and penetration into the inner layer insulation in close-up areas. The minimum insulation thickness found in a marked area was 28 um (1.1 mils) as shown in Figures 7 and 8.

Each layer was chemically identified using FTIR. The outer white and inner white, semitransparent layers were nearly identical and the spectra most closely matched references for polyimide materials based on pyromellitic anhydride and an aliphatic diamine. The FTIR spectra for the middle amber layer most closely matched references for polyimide materials based on pyromellitic anhydride and diaminodiphenyl ether. A spectrum for each layer is given in Figures 9, 10, and 11).

SUMMARY OF FINDINGS

In many areas the hot stamp marking process penetrated all three layers of wire insulation.

There was considerable variability in the depth penetration of the hot stamp marks.

Cracks initiated from several hot stamp marks.

The mark sites did not exhibit any arc tracking or propagation damage typically associated with sustained current flow.

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