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**TWA 800 Switch Analysis**
**(Failure Analysis)**

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**Evaluation Report**
**(4349LABR/NTSB)**

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# TWA 800 Switch Analysis

## PURPOSE

Examine and electrically characterize switches for any anomalies and witness marks.

## BACKGROUND

The three switches, scavenge, right, and left jettison switches, had been previously examined by personnel at NASA. The scavenge pump switch was reported to be in the "off" position and volt meter tests confirmed this conclusion. The contacts exhibited a high resistance of 400 ohms when the scavenge pump switch was in the "on" position. Both jettison switches were observed and confirmed with the volt meter to be in the "off" position. The S-16 (left jettison switch) switch had 0.3 ohm contact resistance, while S-17 (right jettison switch) had 0.28 ohm contact resistance in the "on" position. The left jettison pump switch toggle was observed to be smashed downward toward the "off" position. The toggle seal was damaged. The toggle of the right jettison switch was observed to be in the "off" position. The seal was also damaged.

## FACTUAL DATA

As part of the TWA 800 mishap investigation, three environmentally sealed switches were analyzed as requested by NTSB. Another like design switch (S-11) was examined for comparison. The three switches consisted of the Right and Left Jettison Switches and Scavenge Pump Switch. The one of similar construction to the Right and Left Jettison Switches examined for comparison was the S-11 switch from the flight engineer's fuel control panel. All three switches were photographed as received (Figures 1 and 2). The flight engineer's fuel control panel from which the switches had been removed was also received (Figures 3 and 4).

Initially, the three switches were examined using real time X-ray. The results were documented on video tape. No anomalies were noted.

The right and left jettison switches were the same model (1TL-3) and date code 7042. The switches had been labeled with a black marker to indicate the switch functions and terminal positions.

The left jettison switch knob was bent towards the "off" position (bottom) 50 degrees beyond normal. The markings and the bent knob are shown in Figures 1 and 2. Corrosion was noted around the three contact screws (designated as top, left, and bottom) (Figure 5). The terminal wire was attached to the bottom screw terminal. The left screw terminal contact was in place but the wire had broken away at the lug terminal. There was no wire attached to the top terminal. There was green-colored corrosion around the terminal attachment. The exposed copper was also green colored. The copper was partly shiny on the broken solderless terminal connector (see arrow, Figure 5). The top terminal appears to have been unused. Corrosion was noted on top of the switch and around the securing threads and inside the top one. There was a deep gouge in the securing thread. The case exhibited some corrosion and the blue colored case material was flaking off. The corrosion was primarily white in color with some green coloration. The metal surrounding the environmental seal had corrosion and salt water-like and sand deposits (Figure 6).

The right jettison switch had a similar appearance. It was received in the "off" position. There were gouges in the securing bushing. The screw terminals (labeled top, right, and bottom) were similar in appearance to the left jettison switch. The metal surrounding the environmental seal had corrosion and salt water-like deposits. There was green and white colored corrosion on the screws and threads. The right and bottom screw terminals had wires attached.

The scavenge pump switch had a locking feature (MS24658-23G) in the "off" position. By design the knob would have to be pulled out and over the stop to move to the "on" position. It was received in the "off" position. The date code on the switch was 7038. The screw terminals were intact and connected to the center and bottom positions. They exhibited green-colored and white-colored corrosion and salt water-like residues. A gouge was found on the forward side (as installed) of the switch knob, 15° above the knob center line (Figures 7 and 8). This gouge was examined in the scanning electron microscope (SEM) and analyzed using energy dispersive spectroscopy (EDS) (Figure 9). The metal displacement in the gouge was consistent with a tangential impact to the switch knob in the direction as diagrammed in Figure 10. The EDS analysis of the gouge area (Figure 11) indicates the knob construction materials are a nickel plated brass (zinc and copper). No foreign materials were identified in the areas analyzed to reveal the makeup of the object that impacted the knob. The knob locking cam exhibited rust-colored corrosion and salt water-like residues around the base and along the back side of the knob. Examination of the switch knob placement while in the locked "off" position revealed evidence it had been displaced toward the right side of the switch. Optical inspection also showed evidence the knob was displaced towards the right side of the locking cam (Figure 12). The locking cam groove for the "off" position on the right side had metal displacement in the shape of a lip (Figures 13 and 14). The environmental seal sleeve around the knob was stretched away from the knob towards the "on" position (Figure 15). The locking cam surface was examined for any witness marks which would indicate a blow to the knob and none were found. The wear pattern appeared normal.

Electrical measurements consisting of insulation resistance and contact resistance were made on the three switches. Insulation resistance measurements were made using an HP 4329A high resistance meter at 500 VDC after one minute stabilization at 23°C and 62% RH. Contact resistance measurements were made at 10 mA, using the four point probe method. A Keithley 2001 was used to measure the voltage. The constant current was supplied by an HP6227B and measured by an HP3478A. A Tektronix 576 curve tracer was used to make the initial measurements on the scavenge pump switch so as not to destroy any failure evidence. The resistance exceeded the internal resistance of the instrument. The results are compiled in Table 1.

Actuation forces were determined for the three switches using a Chatillon digital force gauge (DFG100). The results are compiled in Table 2.

The switches were opened for internal inspection by the following process. Each plastic case was thinned on both sides by sanding with 240 grit sand paper. The thinned cases were then cut and pried open using a knife. The internal switching mechanisms could then be examined in detail. All three switch plunger guides showed evidence of removal from an injection mold runner (Figures 16 and 17). All three switches had various amounts of salt-like deposits on most of the internal part surfaces (Figure 18). Inside the switches, there is a rocker arm that contains a moving contact on each end and pivots at the center when the switch is activated or deactivated (Figures 19-21). A plunger attached to the external knob moves laterally along this rocker arm along a track (Figure 17). The plungers all exhibited black marks resulting from actuation impact with the plunger stop (Figure 22). Along the track of the plunger, there is a red colored lubricant, applied during manufacture (Figure 22). Residues from this brown and red colored lubricant were found outside the normal plunger track marks and on the plunger in all four switches examined. The change in color found in the right and left jettison and scavenge pump switches is consistent with sea water exposure based on chemical analysis.

The contact surfaces of all three switches were examined and only the normal wear pattern was found (Figure 23). The normally open contact surfaces in right jettison pump switch were covered with salt water-like residues (Figure 24). Contact resistance for the normally open contacts when actuated was 825 mΩ. The normally closed contact surfaces did not exhibit any salt water-like residues (Figure 25). The contact resistance as expected was much lower at 2.7 mΩ. There appeared to be little or no salt water-like residues on the contact surfaces of the left jettison switch. The contact resistances for the normally open and normally closed were 17.3 mΩ and 20 mΩ, respectively. The normally closed contact surfaces of the scavenge pump switch were clean with a contact resistance reading of 3.8 mΩ. There were slight salt water-like residues on the normally open contact surfaces resulting in a 22.2 kΩ contact resistance (Figure 26).

Switch number S11 was removed as a test specimen to ascertain the effects of a static 25 pound side thrust on the actuator knob. This value was the maximum specified in the military specification MS24523 for this switch design. Sideways displacement of the knob was measured at 5 pound increments up to the 25 pound maximum. This was done to both sides of the switch. The maximum knob displacement was 0.085 inch one direction and 0.066 inch in the other direction. Internal parts would be displaced approximately seven eighths of this amount. This value was determined from the ratio of the distance from the pivot axis to the internal plunger (0.7 inch) to the distance from the pivot axis to the actuating knob end (0.8 inch).

Switch number S11 was also used as a test specimen to observe the effects of impacts on the actuator knob. The test apparatus was a Universal Impact Tester Model #172. This tester consists of a set of weights and a drop tube. One of the weights of this tester had a threaded hole on one end. A large bolt was installed in this hole and the bolt head was used as the contacting surface that collided against the switch knob. This assembly weighed 2.15 pounds and was dropped from a height of 1, 2, 4, and 8 inches. The bolt head height below the bottom stop of the tester drop tube was adjusted to the thickness of the switch knob of 0.24 inch. This produced an overtravel of less than 0.24 inch for the knob and guaranteed most of the drop energy was transferred into the switch. The impacts from four different heights were applied in the "on" to "off" direction of knob travel. The switch was set to "on" position for each impact. Then the impacts were repeated at right angles to the previous impact direction and parallel to the pivot pin of the knob. This test produced nicks in the actuator knob metal at the area of impact. Internal inspection found additional black residue on the white plunger guide where it would contact the switch front faceplate during overtravel. The side impacts loosened the knob pivot pin from one side of the mounting bushing. The test scraped off-center tracks into the contact rocker arm. The switch was disassembled and is shown in exploded view in Figure 27.

The S-11, left and right jettison, and the scavenge pump switches were submitted for chemical analysis. The areas of interest were deposits found on the rocker arms and inside the casings of the switch samples. The rocker arm refers to the silver-colored metal plate that moves when the switch is operated. The samples were examined by means of low power optical microscopy and portions of the deposits were removed and analyzed by means of microscopic Fourier transform infrared spectrometry (FTIR). The results are as follows. FTIR spectra were obtained for the semi-solid red deposit on the S-11 rocker. The spectra obtained were consistent with references that suggested the deposit was an ester based lubricant with lithium stearate (Figure 28). Spectra for deposits on the rocker of the left jettison switch indicated the presence of the same lubricant. Various deposits were observed inside the casings of the left, right, and scavenge switches. These included methyl silicone materials, phthalate ester based materials, polyamide or urea type resins, hydrated inorganic oxides or hydroxides, inorganic carbonates and an unidentified material that exhibits absorptions in a spectral region expected for inorganic nitrates and organic nitro compounds.

**Summary of Findings**

All three switches were received in the "off" position. The worst external damage, a bent knob, occurred on the left jettison switch.

Salt water-like residues and contamination on the contact surfaces of the switches indicate the contacts were received in the same position as they were in when recovered from the mishap site. Residues and contamination prevented accurate contact resistance measurements and resulted in higher readings. The right jettison switch contained the most contamination.

No discernible witness marks were found on any of the switches to indicate switch position during the initial stages of the mishap. Mechanical operation and contact appearance of all three switches were normal.

The metal displacement in the gouge found on the scavenge pump switch knob was consistent with an impact to the switch knob in the direction as diagrammed in Figure 10. Since the impact was forward of the knob center line, the resultant force on the knob would be towards the "off" position. The EDS analysis was unable to determine the makeup of the material that caused the gouge. This was due to insufficient amount of material for analysis or because the impact object was constructed from the same material as the knob.

There was no evidence to support any forced movement to the "off" position by impact or some other means from the mishap breakup energy.

**RECOMMENDATION(S)**

None. Data submitted as requested.

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PUBLICATION REVIEW: This report has been reviewed and approved.

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# CONTRACTED LABORATORY DOCUMENTATION INDEX

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ERRATA NOTICE: Airplane N93105 (serial number 19671) was a B-747 airplane that had been retired from service by TWA, prior to the accident involving N93119. The TWA fleet identification for N93105 was "airplane number 17105." A mistake in the record of a Systems Group activity wrongly identified the N93105 airplane as N17105. This mistaken identification was used by subsequent activities, such as at Wright Laboratory, and is referenced in their reports.