National Transportation Safety Board
Washington, D.C. 20594
Safety Recommendation

Date: April 7, 1998

In reply refer to: A-98-34 through -39

Honorable Jane F. Garvey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On July 17, 1996, about 2031 eastern daylight time, a Boeing 747-131, N93119, operated as Trans World Airlines (TWA) flight 800, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport, Jamaica, New York. All 230 people aboard the airplane were killed. The airplane, which was operated under Title 14 Code of Federal Regulations (CFR) Part 121, was bound for Charles De Gaulle International Airport, Paris, France. The flight data recorder and cockpit voice recorder ended simultaneously, about 12 minutes after takeoff. Evidence indicates that as the airplane was climbing near 13,800 feet mean sea level, an in-flight explosion occurred in the center wing fuel tank (CWT), which was nearly empty.

The source of ignition of the CWT has not been determined, and the investigation into a variety of potential ignition sources continues. However, the Safety Board's investigation has found damaged wiring in the fuel quantity indication systems (FQIS)[1,2] of the accident airplane

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[1] The B-747 FQIS measures fuel quantity with a capacitance measurement fuel probe system in each fuel tank. There are seven capacitance measurement fuel probes in the B-747 CWT. Each fuel probe consists of an inner tubular element that is surrounded by an outer tube. Compensators, located near the low point of each fuel tank, are also constructed of assemblies of tubular elements. The compensators and probes have a hard plastic terminal block near the top of each to provide for wiring connections. Wires from each fuel probe and the compensator are routed within the fuel tank through nylon clips to a connector located at the rear wing spar and are exposed to fuel and vapor.

[2] Most of the B-747-100, -200, and -300 series airplanes (about 700 airplanes) are equipped with FQIS manufactured by Honeywell Corporation; airplanes equipped with the Honeywell system are the subject of this letter. About 10 percent of the B-747-100, -200, and -300 series fleet has been retrofitted with FQIS manufactured by BFGoodrich Aerospace Corporation (formerly Simmonds Precision). The B-747-400 series airplanes are equipped with the BFGoodrich system equipment. No BFGoodrich FQIS were inspected during the investigation.

and three retired B-747s: N93105[3] and N93117[4] and a former Air France airplane, F-BPVE,[5] and the Safety Board was informed of damaged FQIS wiring in a British Airways B-747, G-BBPU.[6] These findings illustrate unsafe conditions that may exist in other B-747s and should be addressed by the Federal Aviation Administration (FAA).

The potential hazardous features found inside of B-747 fuel tanks during the investigation include the following:

1. FQIS wire insulation had been damaged near the attachment point of wires to four CWT fuel probe and compensator terminal blocks in N93105.[7] Terminal blocks with knurled (rough) areas on the surface had Honeywell Corporation manufacturing dates of November 1970[8] and earlier and were identified as Series 1, 2, and 3.[9] These terminal blocks had a metal strain relief clamp pressing the FQIS wires against the knurling. The knurled area consisted of a series of relatively sharp pointed cones in the hard plastic, and the edges of the terminal block castings transected the cones, thus creating sharp edges resembling saw teeth. The FQIS wire insulation had been cut by the knurled area, exposing the core conductors of some wires to the grounded shielding of others.[10]

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[3] N93105 had been undergoing maintenance when it was retired from service by TWA in 1994. The airplane had been in storage in Kansas City since that time.

[4] N93117 had been sold by TWA in 1992, and was subsequently placed in storage in Mojave, California, after 77,145 flight hours.

[5] F-BPVE was retired by Air France in September 1994. The airplane was subsequently used by the Safety Board and other agencies for testing in Bruntingthorpe, England.

[6] G-BBPU is an in-service B-747-136. At the time of its inspection on November 1, 1996, the airplane had been operated 89,639 hours and 17,437 cycles since new.

[7] Few terminal blocks from N93119 were recovered and most of those were fragmented or otherwise damaged. Although few of the fragments had attached FQIS wires, chemical traces on the exterior of damaged wire insulation had been deposited on and around previously damaged surfaces. Damage similar to that found in N93105 has been seen in some FQIS components from F-BPVE.

[8] On May 28, 1969, Boeing implemented a requirement for the wires to withstand a 50-pound pull, and on December 29, 1969, Honeywell Engineering Change Order 69 15826 revised the design to a Series 4 terminal block, which deleted the use of screws to fasten FQIS wires to the terminal block and introduced the use of threaded studs and nuts. On the Series 4 block, the metal strain relief clamp and knurling were deleted and the FQIS wires were held within the eye of a "P"-shaped nylon clamp that held the wiring above the terminal block surface. The change order was to be effective as soon as new terminal blocks were available. Boeing reported that a production change was made at Boeing that installed the Series 4 terminal blocks in [airplane] line number 65 and onward. Since N93119 was line number 153 and was delivered on October 27, 1971, Boeing concluded that it was improbable that it was delivered with Series 3 terminal block probes. A mixture of terminal block series that included Series 1-3 and subsequent designs were found in each of the cited B-747 airplanes, including N93119.

[9] The Honeywell Component Maintenance Manual still shows the Series 1-3 terminal blocks and metal strain relief clamps as "applicable" [acceptable] for use. Honeywell has reportedly supplied them as replacement parts, although only the updated design is now sold.

[10] Wire shielding covers the inner insulation and core conductor with a layer of woven wire, which isolates the conductor from electromagnetic signals and provides protection to the inner insulation and core conductor from external mechanical damage. Additional insulation covers the wire shielding.

2. In addition to the knurled surfaces found in the Series 1-3 fuel probes, B-747 fuel probe terminal blocks and compensators have squared edges that can damage wire insulation. A wire that had been located against the edge of a Series 1-3 terminal block from N93105 had a lengthwise cut in its insulation. (In contrast to the B-747 Series 1-3 terminal blocks, Honeywell also makes B-757 and B-767 fuel probes with terminal block edges that are smooth and rounded.)

3. The insulation of a fuel probe wire from the CWT in N93105 was also found to be displaced (cold-flowed), exposing its core conductor. The wire had been one of several pressed under the strain relief clamp of a Series 1-3 fuel probe terminal block. Wire insulation was also displaced by cold-flow or chafe at points of tight contact between wires not under the knurled clamps and where wires were pressed against plastic heat-shrink material on adjacent wires, in some instances exposing the conductor of one wire to the shield of a second wire. Displaced insulation that had been damaged but not breached was identified at various locations where wires pressed against other wires, where wires were in contact with the edge of a clamp, and at the edges of nylon clips where the FQIS wire routing made sharp turns inside the fuel tanks. Points of chafing and potential chafing were also found where FQIS wires contacted structure in the CWT of N93117.

4. During the accident investigation, two inappropriate repairs were found in the FQIS wiring in the wing tip fuel tanks of the accident airplane and another inappropriate repair was found by Boeing in a B-747 operated by another airline. The shielding of an N93119 wingtip tank FQIS probe wire had been previously broken and repaired. The repair of the wire consisted of splicing with a crimped connector and covering it with adhesive tape secured by wire bundle lacing tape.[11] Although the repair was functional, separated wire strands were found at the edge of the crimped connector. The separated strands had flat and angled-surface features, indicative of a fatigue failure. Boeing recommends that such broken FQIS wire be removed, solder-repaired, and covered with heat-shrink tubing. The second inappropriate repair found in N93119 was on a post-Series 3 compensator, where an oversized terminal block strain relief "P-clamp" had been used. The replacement P-clamp was larger than specified and unable to grip the FQIS wire harness. To provide strain relief, the wire harness had been looped to pass through the clamp twice and was still a loose fit. The third inappropriate repair was found in the CWT

[11] Wiring in B-747s is assembled into harnesses with lacing tape made of Dacron, fiberglass, or Nomex, as specified in the Boeing Standard Wiring Practices Manual, section 20-00-11, page 17, Table XX, "Tie Materials."

of G-BBPU, where chafed FQIS wires had been repaired with fuel tank sealant.[12]

The damaged wiring at the terminal blocks was found only after the wiring had been removed. A close visual inspection in the tank without removing the wires would have been insufficient to disclose damage that is concealed between wires or under wire clamps. These types of damage could create spark gaps that are very small and that could become latent failures in the wiring system.

Boeing issued Service Bulletin (SB) 747-28-2205 on June 27, 1997, and a notice of status change for this SB on September 25, 1997, to address B-747 fuel tank inspection procedures. However, the recommended inspection procedures for FQIS wires, fuel probes, and compensators were not addressed in sufficient depth for operators to find wire insulation damage similar to that found during the TWA 800 accident investigation. Most of the damaged FQIS wire insulation found during the accident investigation was concealed beneath strain relief clamps or other wires and was discovered only after the wiring was removed from terminal blocks. In some cases, the damage was not apparent until the ends of the wires were inspected under magnification.

On October 27, 1997, Boeing issued a notice to B-747 operators (M-7220-97-1725) describing a planned SB that would provide further details on inspecting B-747 fuel probes, compensators, and FQIS wires. In an October 30, 1997, letter to the Safety Board, Boeing stated that the new SB will recommend the replacement of Series 1-3 fuel probes, the reporting of damage involving Series 4 and later fuel probes, the replacement of certain CWT FQIS wire harnesses, and the inspection for proper wire routing and existing damage; the SB will also establish an electrical resistance check of very low voltage and establish standards for FQIS repairs.

The Safety Board appreciates Boeing's efforts to develop a new SB to improve inspection of B-747 CWT FQIS components. However, compliance with SBs is not mandatory. The Safety Board believes that the FAA should issue, as soon as possible, an airworthiness directive (AD) to require a detailed inspection of FQIS wiring in B-747-100, -200, and -300 series airplane fuel tanks for damage, and the replacement or the repair of any wires found to be damaged. Wires on Honeywell Series 1-3 probes and compensators should be removed for examination.

In December 1969, Boeing reportedly discontinued using the Honeywell Corporation Series 1-3 fuel probes (with knurled terminal block surfaces and metal strain relief clamps) and began using the Series 4 (and later) fuel probes[13] as a product improvement. However, the change was not considered mandatory and Series 1-3 fuel probes are still found in airplanes. This investigation has shown that the knurling and the sharp edges of the early design terminal

[12] The Boeing Standard Wiring Practices Manual describes methods and materials that can be used for wire repairs. It does not list fuel tank sealant as an approved material for repair of electrical wiring.

[13] See footnote 7.

blocks create damage to wire insulation. Changing to a Series 4 terminal block reduced the potential for FQIS wires to be damaged by the terminal blocks. However, the Honeywell overhaul manual still shows the Honeywell Series 1-3 terminal blocks as "applicable for use." The Safety Board believes that the FAA should issue an AD to require the earliest possible replacement of the Honeywell Corporation Series 1-3 terminal blocks used on B-747 fuel probes with terminal blocks that do not have knurled surfaces or sharp edges that may damage FQIS wiring.

Features of the fuel probes and wiring installation used in B-747s are similar to those of Honeywell fuel probes used in other airplanes, including the B-707, Lockheed C-130, B-757, and B-767. The B-707 and C-130 terminal blocks have a different shape but have some features similar to the B-747 design, including sharp edges. The B-757 and B-767 fuel probe terminal blocks have rounded edges and cast wire relief areas that are not used in the B-747 terminal blocks; the FQIS wires are retained in the cast wire relief areas by a flat metal bar. Wiring attached to the terminal blocks in airplanes other than the B-747 has not been examined by the Safety Board staff during the TWA 800 investigation. However, because of the similarities found during a review of fuel probe designs, the Safety Board is concerned that FQIS wiring problems discovered in this investigation may also exist in other airplanes with similar designs. Therefore, the Safety Board believes that the FAA should conduct a survey of FQIS probes and wires in B-747s equipped with systems other than Honeywell Series 1-3 probes and compensators and in other model airplanes that are used in 14 CFR Part 121 service to determine whether potential fuel tank ignition sources exist that are similar to those found in the B-747. The survey should include removing wires from fuel probes and examining the wires for damage. Repair or replacement procedures for any damaged wires that are found should be developed.[14]

Dark deposits were found around the wiring connections of fuel probes that had been removed from various fuel tanks in N93105, N93117, N93119, and F-BPVE. The deposits were found on wire insulation and on numerous plastic sleeves of crimped wire splices. A scanning electron microscope revealed that the dark deposits on N93119 and N93105 fuel probes contained copper, silver (silver-plated copper wiring is used in fuel tanks), and sulfur (a contaminant in jet fuel). The deposits on an N93119 FQIS compensator fragment were further examined at a U.S. Air Force research laboratory (Wright Laboratory) and were determined to be similar to copper sulfide deposits found in previous examinations of fuel probes from military aircraft. The laboratory had previously found that the deposits gradually reduced resistance between electrical connections of the military airplane fuel probes.

Wright Laboratory staff received a fuel probe that had been removed from a military trainer and tested at a maintenance depot while the probe was still wet with fuel. The test involved voltage and current levels greater than those that would be available from the FQIS. According to the Wright Laboratory staff, disassembly of the probe revealed soot and carbonized copper-sulfide deposits, apparently from the ignition of fuel vapors. A report by the Wright

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[14] Boeing is currently conducting a survey of Honeywell Series 4 probes and compensators.

Laboratory[15] states that a subsequent visual inspection found "discoloration and possible arcing on the bottom" of the probe. The report stated further, "It appears the internal probe wires were damaged by a fire. Evidence of an electrical arc was evident on the nylon cap which would have provided the required energy needed to ignite residual fuel." Another fuel probe documented by the same set of reports had evidence of an arc-track[16] with deposits composed of copper sulfide and carbon. Unburned deposits that were photographed by a scanning electron microscope had the appearance of flaking paint. Electronic testing for the resistance value of similar deposits on a third fuel probe revealed "small scintillating arcs" between the flakes, as current was increased to 5 milliamperes (voltage unknown) between a set of probes located 10 millimeters apart. When drops of JP-4 fuel were placed on the arcing deposit, the report said, "heat generated by the [electric] current rapidly evaporated the fuel. Resistance increased from 13,200 ohms to an open circuit (>20M)[17] after a few seconds." The flaking copper sulfide deposits were found to be a brittle substance that clung tenaciously to plastic materials and could only be cleaned by mechanical abrasion. The report concluded the following:

> The residues act as a thin film resistor that will rupture and open if significant current is passed through the material. Residue formation is most likely the result of a long-term degradation or corrosion process. Exposed silver plated copper wiring and other silver containing surfaces (electrodes) are apparently reacting with the sulfur in the fuel. This deterioration process is most likely time dependent and, as the probes age, more probe [calibration] failures can be expected.

Copper sulfide deposits were found inside the FQIS wire insulation of N93105 and N93119, where the wires had damaged insulation. The Safety Board is concerned that copper sulfide deposits on FQIS wires could become ignition sources in B-747 and similarly designed fuel tanks. The Safety Board believes that the FAA should require research into copper-sulfide deposits on FQIS parts in fuel tanks to determine the levels of deposits that may be hazardous, how to inspect and clean the deposits, and when to replace the components.

The investigation has also found that although the design for the B-747 CWT FQIS provides for limited electrical power in the fuel tank,[18] the FQIS wires are routed in bundles with nearly 400 other wires, some of which carry up to 350 volts.[19] The FQIS harness routed between

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[15] Wright Laboratory Report "Analysis of Trainer Aircraft Fuel Probes I," dated March 1990, by George Slenski, Materials Integrity Branch, Systems Support Division, Materials Directorate.

[16] Arc-tracking is an insulation failure leading to flashover. Tracks develop along the discharge path on the surface of the insulation. The tracks are generally more conductive than the virgin insulation. These tracks carbonize quickly into significant conducting paths.

[17] Mega-ohms are one million ohms of electrical resistance.

[18] Power to the FQIS is limited by Boeing to 0.02 millijoules, or less than 10 percent of minimum ignition energy (MIE) required to ignite Jet A fuel under laboratory conditions, according to the American Petroleum Institute Recommended Practice 2003, Fifth Edition, December 1991, entitled "Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents."

[19] Zone A ceiling light wire W-1306-L1892-22 carries up to 350 volts. Numerous other wires carry 115 volts alternating current (VAC) and 28 volts direct current and are routed in bundles with FQIS system wires. Boeing

the CWT and the flight engineer's panel in the cockpit contains one shielded wire and two unshielded wires in a woven fiberglass sleeve. Boeing noted in an October 27, 1997, letter that this is a common design for capacitive FQIS systems. Behind the flight engineer's panel, the sleeved set of Teflon-insulated FQIS wires was connected to unprotected[20] general airplane wiring[21] that was routed to the fuel totalizer indicator and to the electrical/equipment (E/E) compartment located beneath the forward cabin and behind the nose landing gear. Additionally, unshielded Teflon wiring from the right wing fuel tanks was attached to a terminal strip located on spanwise beam No. 2 in the CWT, then was routed through the left wing fuel tanks to the ground refueling panel gauges located between the Nos. 1 and 2 engines. At the ground refueling panel, the fuel tank wiring was routed with other aircraft wiring for the refueling indicators and controls.

Electrical short circuits can introduce high voltage into low voltage conductors. For example, it was determined that a military C-130 fuel tank exploded in the 1970s after improper maintenance had created a short circuit within a fuel gauge electrical connector.[22] Maintenance work on the connector was not finished before the flight, and the investigation found that 115 VAC power was inadvertently allowed to enter the fuel tank through the shielding of FQIS wires.

In the investigation of a May 11, 1990, Philippine Airlines B-737-300 CWT explosion at Ninoy Aquino International Airport, Manila, Philippines, the exact source of ignition was never established. However, the Safety Board later concluded, "It is possible that the combination of a faulty float switch and damaged wires providing a continuous power supply to the float switch may have caused an electrical arc or overheating of the switch leading to the ignition of the center fuel tank vapor." [23]

An Air Force study[24] of data from 1986 to 1989 mishaps[25] caused by electrical failures found 652 records, of which 326 were examined in detail. Of the 326 reports, 49 involved "conductors" (typically aircraft wiring) and 51 involved "connectors" of numerous types. The study concluded the following:

RA164 Center Wing Tank Wire Bundle Analysis Report, December 17, 1996, indicates bundle No. W186 contains 12 192-volt wires for the flight engineer panel lighting.

[20] Wires that were not isolated or shielded and that were routed in bundles with other wires, some of which carried power for other airplane systems.

[21] Wire markings identified the general N93119 aircraft wiring as (Boeing Specification) BMS13-42A, marketed by Raychem. The wire was sold commercially under the trade name "Poly-X." Other types of wire were also used in the construction of B-747 airplanes.

[22] The Safety Board was permitted to review a report regarding a military C-130 fuel tank explosion that occurred after improper maintenance created a short circuit that created an ignition source in the fuel tank. The airplane identification and the date and location of the incident have not been released.

[23] National Transportation Safety Board. August 1, 1990. Safety Recommendations A-90-100 through -103.

[24] Contract F33615-89-C-5647, completed January 1989, to develop a handbook for the evaluation of electrical components in aircraft accident investigations.

[25] According to the Air Force, there are four classes of mishaps in the Norton database [of USAF mishaps]. Classes A, B, and C generally represent in-flight conditions that result in some damage to the aircraft. The fourth class includes potential mishaps, which may be the result of unusual conditions observed during maintenance or preflight checks.

> The majority of aircraft mishaps involving electronics are related to interconnection problems. Interconnection problems are primarily due to wiring and connector failures. Chafing, which results in electrical arcing of wiring, and corrosion, which results in the electrical breakdown in connectors, appear to be the dominate failure mechanisms.

Such findings are not unique to military mishaps. For example, on July 19, 1997, a Lufthansa B-747 freighter (D-ABZC) was on final approach to JFK International Airport, New York, when seven circuit breakers popped in the cockpit. Afterward, maintenance personnel found 47 (non-FQIS) wires burned in more than 8 inches of the affected wire bundle; the wires were located beneath the oxygen bottles in the "cheek" area to the right of the forward cargo compartment. The wires led to the leading and trailing edge flaps, landing gear circuitry, and the anticollision lights. Circuitry for the wing flap asymmetry detection and a flap electrical drive motor led to the burned area, and each of those components needed replacement. The airplane had been purchased from another carrier and, in April 1993, was modified by a third company to the freighter configuration. Lufthansa found that this airplane and five others that were modified by the same company had metal drill shavings and other debris in that area of the wire bundle. The incident demonstrated the danger of allowing metal shavings to remain on wiring and the possibility of introducing enough electrical energy into unrelated circuits to damage electrical components.

In addition to investigating the potential for introducing energy into FQIS wires from direct short circuits, tests were conducted to determine the energy that can be induced into unshielded FQIS wires by electromagnetic inductance (EMI). Laboratory tests[26] have shown that EMI can introduce elevated levels of energy into FQIS wiring, and sparks can be induced by adding foreign material to the fuel probes, thus creating spark gaps. This amount of energy was only found during tests in which a spark gap was artificially created between the Lo-Z (outer fuel probe electrode or terminal) and ground. To date, testing has not duplicated those results on an airplane. The investigation of this issue is continuing.

Wire shielding and physical separation each provide EMI and chafe protection for the inner conductor and a path to ground for short circuits from other wires and are widely used in airplanes. However, two of the three recovered FQIS wires from N93119 that had been routed between the CWT and the cockpit in a woven sleeve were not protected from EMI or chafing by shielding or separation from other wires. Also, BMS13-42A wires that were found routed from the cockpit end of the FQIS harness to the E/E compartment were not shielded or separated. In 1974, Boeing incorporated an overall shield around all three CWT FQIS wires routed between the CWT and flight engineer panel; in 1980, Boeing added further shielding to FQIS wires behind the flight engineer panel. However, these wiring changes were not required for previously manufactured airplanes, such as N93119. In its October 27, 1997, letter, Boeing

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[26] Tests were conducted to Boeing specification to create transient voltages and sparks by switching electrical power on and off in wires that had been laid parallel to the CWT bundle. Tests induced up to 0.060 millijoules of energy in the CWT harness, exceeding the API practice 2003 reference for an MIE requirement of 0.025 millijoules.

acknowledged the additional benefits of shielding, but wrote that the shielded wire was used to correct for electrical noise in the FQIS wires (not for EMI or chafe protection).

The Safety Board recognizes the difficulty and expense associated with physically separating FQIS wires from other wires and adding shielding to FQIS wires on in-service air carrier airplanes. Access is limited behind avionic racks and at bulkhead electrical connectors, and rewiring is labor intensive. However, the separation of the FQIS from other power sources by shielding and separation can protect fuel tank wires from power sources that can potentially ignite an explosive vapor in a fuel tank. The Safety Board believes that the FAA should require in B-747 airplanes, and in other airplanes with FQIS wire installations that are corouted with wires that may be powered, the physical separation and electrical shielding of FQIS wires to the maximum extent possible.

Because of the variety of latent potential ignition sources found in B-747 fuel tanks, and the variety of means by which energy can be introduced into FQIS wires, the Safety Board does not believe that correcting wiring deficiencies and addressing system failures would fully protect the B-747 CWT and other fuel tanks against all potential ignition sources. Total FQIS wire shielding or separation from other wires would be very difficult to change in airplanes already in service and would not address failures within system components, such as fuel gauges, ground refueling volumetric shutoffs, and data acquisition units. Unless the volatility of fuel tank vapors can be eliminated as a potential hazard, electrical power surge suppressers may be the most effective method of preventing the FQIS from becoming an ignition source. On December 1, 1997, the FAA issued a notice of proposed rulemaking applicable to B-747-100, -200, and -300 series airplanes that agreed with this premise and would require either the installation of components for the suppression of electrical transients by electromagnetic interference, or the shielding and separation of the electrical wiring of the FQIS.

Surge suppressors installed where FQIS wires enter fuel tanks could provide added protection against excessive power surges in the FQIS system, regardless of origin. Surge protection systems are used in a range of devices, from autopilots to personal computers. Boeing has successfully used electrical surge suppression in other applications, but has noted that extreme care would have to be used in an FQIS application to account for possible influences on system operation and failure modes. Because the basic concepts of most capacitance FQIS systems are similar, the Safety Board believes that the FAA should require, in all applicable transport airplane fuel tanks, surge protection systems to prevent electrical power surges from entering fuel tanks through FQIS wires.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Issue, as soon as possible, an airworthiness directive to require a detailed inspection of fuel quantity indication system wiring in Boeing 747-100, -200, and -300 series airplane fuel tanks for damage, and the replacement or the repair of

any wires found to be damaged. Wires on Honeywell Series 1-3 probes and compensators should be removed for examination. (A-98-34)

Issue an airworthiness directive to require the earliest possible replacement of the Honeywell Corporation Series 1-3 terminal blocks used on Boeing 747 fuel probes with terminal blocks that do not have knurled surfaces or sharp edges that may damage fuel quantity indication system wiring. (A-98-35)

Conduct a survey of fuel quantity indication system probes and wires in Boeing 747s equipped with systems other than Honeywell Series 1-3 probes and compensators and in other model airplanes that are used in Title 14 Code of Federal Regulations Part 121 service to determine whether potential fuel tank ignition sources exist that are similar to those found in the Boeing 747. The survey should include removing wires from fuel probes and examining the wires for damage. Repair or replacement procedures for any damaged wires that are found should be developed. (A-98-36)

Require research into copper-sulfide deposits on fuel quantity indication system parts in fuel tanks to determine the levels of deposits that may be hazardous, how to inspect and clean the deposits, and when to replace the components. (A-98-37)

Require in Boeing 747 airplanes, and in other airplanes with fuel quantity indication system (FQIS) wire installations that are corouted with wires that may be powered, the physical separation and electrical shielding of FQIS wires to the maximum extent possible. (A-98-38)

Require, in all applicable transport airplane fuel tanks, surge protection systems to prevent electrical power surges from entering fuel tanks though fuel quantity indication system wires. (A-98-39)

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

[original signed]

By: Jim Hall
Chairman