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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

DCA-90-MA-028

Date: August 1, 1990
In reply refer to: A-90-100 thru -103

Honorable James B. Busey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On May 11, 1990, a Boeing 737-300, Ireland registration EI-BZG, leased to and operated by Philippine Air Lines, exploded and burned at Manila, Republic of the Philippines, shortly after pushback from the ramp. At the time of the accident, the airplane was operating on power from the auxiliary power unit. Of the 119 persons on board, 8 persons were fatally injured and 30 received serious injuries. The airplane was destroyed by fire.

Although the Philippine Government is currently investigating the accident, the National Transportation Safety Board has been involved in the investigation through its U.S. accredited representative in accordance with the provisions of Annex 13 to the International Civil Aviation Organization (ICAO) treaty.

The investigation has found no evidence of a bomb, an incendiary device, or sabotage. Preliminary evidence indicates that ignition of the fuel-air mixture in the center fuel tank was the cause of the explosion and subsequent fire. The investigation has yet to reveal the exact ignition source. Examination of the cockpit voice recorder (CVR) data disclosed that a one-cycle transient spike occurred approximately .2 second before the explosion. The source and nature of the spike -- whether it was electrically induced on the CVR signal wire or electromagnetically picked up by the area microphone or pilot boom microphones -- has not been determined. The investigation has found potential defects involving the center tank float switch and the wiring for the float switch, both of which could have been the source of the ignition. Additionally, interference rub marks were found on the fuel booster pump impeller and pump body.

At the time of the accident, all the fuel boost pumps were in the "ON" position. The center fuel tank had not been filled since March 9, 1990. During the pushback of the airplane the center fuel tank low pressure light illuminated, indicating that the center fuel tank had been emptied of all usable fuel. Laboratory examination of fuel samples from the airplane and fuel storage tanks indicates that the fuel vapor in the center tank would have had a flash point of between 112° and 117° F. At flash point, a heat

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source of between 400° to 500° F or an electrical arc of .25 milli-joule would have been sufficient to initiate an explosion of the fuel-air mixture. Ambient temperature at the time of the accident was 95° F.

Laboratory examination of the float switch (Revere Aerospace part number F8300-146) for the center fuel tank refueling valve has found portions of the switch housing and its reed switch tube missing and metal fragments in the remains of the switch epoxy potting material. The examination of the components and discussions with the manufacturer indicate that it is possible that the switch did not pass inspection when originally assembled. Prior procedures at Revere were to drill out the epoxy potting material and reed switch from the housing then install a new reed switch. This procedure would explain the damage to the switch housing and the metal fragments that were found in the epoxy potting material. Revere modified its procedures approximately 3 years ago to prohibit this practice. All of the float switches that Boeing has in stock, approximately 850, were manufactured prior to this change in procedure. These float switches were subject to dielectric tests at the Boeing Company's facilities. All of the switches passed these tests. However, investigators and laboratory technicians are uncertain as to the efficacy of current acceptance tests and lot sampling procedures. Therefore, the development of additional testing techniques may be necessary. The same model float switch is used on all three fuel tanks in the Boeing 737 series airplanes, in the auxiliary fuel tanks of 100 Boeing 727s, and possibly on other manufacturer's airplanes.

Normally, the fuel tank float switches are only electrically powered when the refueling panel access door is open. The door would have been closed during the pushback of the airplane when the explosion occurred. However, examination of the 28-volt direct-current power wires for the float switch, which lead from the center tank to the refueling panel on the right wing, disclosed an area approximately 3/8 inch long in which the wire insulation had been compromised and the conductor was exposed. The exposed wires were crushed, but no evidence of electrical arcing was found. The exposed section of wire was inside the inboard vapor seal at the right engine pylon. Examination of the wire bundle in the vapor seal revealed several other wires that had damaged insulation and exposed conducting material, including a wire powered by 115-volt alternating current. Further examination of the wire bundles for both the left and right wings found numerous areas in which wire insulation had been damaged.

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.

The investigation determined that after delivery of the airplane, Philippine Air Lines had installed logo lights on the wingtip trailing edges. This installation would have required mechanics to insert additional wires through the vapor seals, the fuselage pressure seal, and inside numerous clamps. Thus, the installation of the wires for the logo lights could have been the source of the damage to wires in the wire bundles. However, the damage may have resulted from the installation of the wire bundle at the

factory because other damaged wires were found that were not related to the installation of the wires for the logo lights. For example, intercom wires in the left fuselage wire bundle were found with damaged insulation and exposed conductor. Additionally, many airplanes are often modified after delivery, requiring the installation of additional wires in the wire bundles of the wings. Boeing has informed the Safety Board that there were minor changes to the wing wire bundles in the 737-300, -400, -500 series airplanes as compared to the 737-100 and -200 series. However, the wire bundle routing and the wire bundle vapor seals are considerably different.

The Safety Board believes that the finding of damaged float switch wiring and a potentially defective float switch, as well as the potential for a fuel tank explosion requires the immediate inspection or testing of float switch wiring of the three fuel tanks on Boeing 737-300, -400, and -500 series airplanes. The Safety Board believes that immediate inspection of the float switch wiring should be accomplished to verify that electrical power is not being supplied to float switches by damaged wiring. Inspection or testing of the float switches should be accomplished after Revere, Boeing, and the Federal Aviation Administration (FAA) are confident that satisfactory testing techniques have been developed.

The Safety Board notes that the FAA has sent a letter to Philippine Air Lines requesting that the other two airplanes modified by the airline be inspected for damaged wiring. The Safety Board does not believe that this action is adequate because it does not address the problem of faulty float switches. Additionally, the FAA action does not decrease the potential of another accident because many airplanes have the same float switch installed and the possibility of damaged wiring exists whether or not the airplane was modified after original manufacture.

The Safety Board believes that it would be prudent, at the next maintenance inspection, for all 14 CFR Part 121 airplanes that have had additional wires added to their wing wire bundles since delivery to be inspected for damage to the wires under the clamps and inside pressure seals and vapor seals.

Lastly, laboratory examination of the left booster pump for the center fuel tank on the accident airplane found evidence of an interference rub between the pump impeller and pump body, and a slight wearing of the bearings. The manufacturer has stated that such material wear is common when pumps have been run in a dry condition. The manufacturer also stated that some operators will let the booster pumps run with a tank empty for extended periods and that no problems have been noted. However the service life of the pump bearings is less than expected. Investigators have been unable to find adequate test data on the dry running of the booster pumps in jet fuel vapor at flash point temperatures to eliminate the rubbing of the pump impeller as a possible ignition source. The Safety Board believes that appropriate tests should be accomplished to determine if the pumps are airworthy for all operating conditions. Such tests would include continuously running the pumps in fuel vapor at flash point with the impeller rubbing the pump body.

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

Issue an airworthiness directive to require immediate inspection or testing of float switch wiring from the float switches to the refueling panel for chaffed or damaged insulation material on Boeing 737-300, -400, and -500 series airplanes. The directive should state that special emphasis be placed on inspecting the wire bundle where it passes through the wing pylon vapor seals and under the wire bundle clamps. (Class I, Urgent Action) (A-90-100)

Develop testing techniques to ensure that float switches manufactured by Revere Aerospace are free from defect that could cause an explosion or fire. After testing techniques are developed, issue an airworthiness directive to require testing of Revere Aerospace float switches and replacement if they are defective. (Class II, Priority Action) (A-90-101)

Issue an airworthiness directive applicable to all 14 CFR Part 121 airplanes to require, at the next scheduled major maintenance inspection, an inspection of the wires in wire bundles in the wings where additional wiring has been added since the airplane was manufactured. The inspection should be directed to the determination of insulation damage where the wire bundle is under clamps and inside vapor seals and pressure seals. (Class II, Priority Action) (A-90-102)

Conduct a detailed engineering design review and testing of the fuel pumps used in the Boeing 737-300 series airplanes (P/N 10-62049-3) to verify that overheating and interference between the rotating components of the pump and its case will not cause a fire hazard. Testing should be conducted in jet-fuel vapor at flash point. (Class II, Priority Action) (A-90-103)

KOLSTAD, Chairman, COUGHLIN, Vice Chairman, and LAUBER, Member, concurred in these recommendations. BURNETT, Member, filed the statement below.

By: James L. Kolstad
Chairman

BURNETT, Member, concurring in part and dissenting in part:

I would have preferred that the first and second recommendations contained in this letter have been worded as originally adopted by the Board as follows:

Issue an airworthiness directive to require immediate inspection or testing of float switch wiring from the float switches to the refueling panel for chaffed or damaged insulation material on all airplanes equipped with float switches manufactured by Revere Aerospace, P/N 8300-146. The directive should state that special emphasis be placed on inspecting the wires where it passes through the wing pylon vapor seals and under the wire bundle clamps. (Class I, Urgent Action)

Issue an airworthiness directive to require testing of Revere Aerospace float switches, P/N F8300-146, and replacement if they are defective. (Class I, Urgent Action)