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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ISSUED: December 5, 1985

Forwarded to:

Honorable Donald D. Engen
Administrator
Federal Aviation Administration
Washington, D. C. 20591

SAFETY RECOMMENDATION(S)

A-85-133 through -137

On August 12, 1985, Japan Air Lines, Flight 123, a Boeing 747SR-100, en route from Tokyo's Haneda Airport to Osaka, crashed into a mountain ridge at an elevation of 1,600 meters about 55 nmi northwest of Haneda. The Government of Japan is continuing its investigation into the facts and circumstances of this accident. However, the investigation has revealed that the airplane experienced a decompression near 24,000 feet and subsequently lost a large portion of the vertical fin and the use of all four hydraulic systems.

Preliminary evidence indicates that the aft pressure bulkhead ruptured in flight while the airplane was over water allowing pressurized cabin air to vent into the unpressurized empennage. As a result, the empennage was subjected to an excessive buildup in pressure differential which damaged the vertical stabilizer. Portions of the upper and lower rudders, the auxiliary power unit (APU), the APU firewall, and the aft torque box of the vertical stabilizer are presumed to have fallen into the sea and have not been recovered.

The Boeing 747 empennage section is designed so that, in the event of exposure to an excessive pressure differential, a vent door will open to relieve the internal pressure before structural damage is incurred. However, preliminary analysis conducted by the airplane manufacturer indicates that the size of the vent door would be inadequate to relieve the high pressure produced when a large area of the bulkhead suddenly opened. Thus, the high pressure differential will cause a structural failure. The aft torque box of the vertical stabilizer was determined to be the first element to fail under such a condition. Since the aft torque box provided the primary structural

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support for the vertical stabilizer to which the rudders were attached, structural damage to the torque box jeopardized the directional stability and control of the airplane. Because of the potential for similar occurrences, the Safety Board believes that design changes should be developed and incorporated into the empennage structure to protect it against catastrophic failure in the event of exposure to a pressure buildup after a bulkhead structural failure.

The loss of all four hydraulic systems apparently occurred because the hydraulic fluid lines located in the empennage were severed when the aft torque box and rudders of the vertical stabilizer separated. The lines of all four systems are routed through this area to hydraulic actuators for the upper rudder and lower rudder, both of which were separated from the vertical stabilizer.

The incorporation of four separate and independent hydraulic systems is intended to provide for redundancy necessary to ensure the continued safe flight and landing of the airplane in the event of hydraulic failures. However, the circumstances of this accident have raised concerns about the adequacy of the redundant design because of the collocation of the lines of all four hydraulic systems in the aft torque box, and the vulnerability of the vertical stabilizers to damage in the event the empennage is exposed to an excessive pressure differential. The Safety Board believes that the design of the hydraulic system in the empennage should be modified to ensure the redundancy intended and to eliminate the vulnerability to failure of all four systems.

The dome-shaped aft pressure bulkhead is a fail-safe design which incorporates four circumferential tear straps around the pressure dome that are riveted to 18 pie-shaped bulkhead sheets with radial stiffeners. The areas of the bulkhead between these tear straps and stiffeners are called bays. The manufacturer indicated that in the event of cracking in the bulkhead sheets, the tear straps are designed to confine the crack propagation to a single bay. The tear straps are supposed to redirect progressive cracking and/or overstress fracture so that the individual sheet metal of a bay panel will flap open allowing for a controlled release of cabin pressure instead of sudden separation across the entire dome and subsequent exposure of the area aft of the bulkhead to an excessive pressure differential.

The "flapping" of one bay is the basis for the "fail-safe" design concept for the Boeing 747 pressure dome. The pressure relief door, which is located on the aft lower fuselage, is designed to limit the pressure differential after such a failure.

To date, the investigation has disclosed that the rupture of the bulkhead may have stemmed from numerous fatigue cracks in the upper dome sheet in an area of an improperly installed splice made during a repair of the bulkhead after a previous landing accident in 1978. During this repair, the damaged lower half of the bulkhead was replaced, and a 36-inch-long splice plate was installed because the upper and lower domes failed to mate. The splice plate, which spanned 2 of the 10 bays along the joint, was improperly installed. As installed, only one line of rivets effectively carried the load into the upper dome sheet instead of two, as intended in the repair engineering. In addition, doubler sheets were installed in the two bays above the splice to correct for oil-can wrinkling of the domed sheet metal material. It was within this area of the improperly installed splice that the rupture initiated.

Preliminary examination of the bulkhead fracture has shown that the bulkhead tear straps did not redirect the cracking and overstress progression of the sheet metal separation as originally intended. Multiple cracks were developing in adjacent bays without the failure of a single bay by the "flapping" concept, and numerous small fatigue cracks were found in the sheet which would not have been detected during normal visual inspection.

Although the Safety Board believes that the improper installation of the designed repair and doubler reinforcement influenced the cracking in this bulkhead, the Safety Board is concerned about the basic "fail-safe" design even in a properly constructed bulkhead. Thus, the Safety Board believes that the basic design, which also was used on the Boeing 767, should be analyzed and tested to assure that the "flapping" concept is valid. Furthermore, approved repairs to this bulkhead design should be examined to ascertain whether the installation of doublers or splices invalidates the "fail-safe" concept.

The Safety Board also is concerned about the approved visual inspection procedures for the aft pressure bulkhead. Visual inspection will not detect small fatigue cracks beneath rivet heads. Furthermore, both the design and inspection procedures should be such that any cracking will be detected before a crack reaches a critical length. The "fail-safe" concept which provides an additional level of safety by limiting the progression of an undetected crack to the failure of one bay with limited pressure change may be invalid if multiple small cracks can progress undetected, thus weakening the entire bulkhead structure. Consequently, the Safety Board believes that the FAA should require Boeing to establish an inspection interval for the bulkhead that includes a more thorough inspection to determine the extent of fatigue, if any.

It appears that the consequences of this accident may have been the result of an isolated and extremely remote occurrence; however, the Safety Board is concerned that certain features of the design of the Boeing 747 empennage make it susceptible to catastrophic damage and loss of controllability in the event of a large cabin depressurization at the aft pressure bulkhead. Therefore, to preclude the possibility of future occurrences of such conditions, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Require the manufacturer to modify the design of the Boeing 747 empennage so that in the event that a significant pressure buildup occurs in the normally unpressurized empennage, the structural integrity of the stabilizers and their respective control surfaces will be protected against catastrophic failure, and to incorporate associated modifications on all Boeing 747 airplanes. (Class II, Priority Action) (A-85-133)

Require the manufacturer to modify the design of the Boeing 747 hydraulic systems so that in the event a significant pressure buildup occurs in the normally unpressurized empennage, the integrity of all four hydraulic systems will not be impaired, and to incorporate associated modifications on all Boeing 747 airplanes. (Class II, Priority Action) (A-85-134)

Reevaluate the design of the Boeing 747 and 767 aft pressure bulkheads by requiring Boeing to analyze and test further the bulkhead to demonstrate the validity of the fail-safe "flapping" failure mode. (Class II, Priority Action) (A-85-135)

Evaluate any procedures approved to repair B-747 and B-767 aft pressure bulkheads to assure that the repairs do not affect the "fail-safe" concept of the bulkhead design which is intended to limit the area of presssure relief in the event of a structural failure. (Class II, Priority Action) (A-85-136)

Revise the inspection program for the B-747 rear pressure bulkhead, to establish an inspection interval wherein inspections beyond the routine visual inspection would be performed to detect the extent of possible multiple site fatigue cracking. (Class II, Priority Action) (A-85-137)

BURNETT, Chairman, GOLDMAN, Vice Chairman, and LAUBER, Member, concurred in these recommendations.

By: Jim Burnett
Chairman