SP-20

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation LOG-2175B

Date: July 21, 1989

In reply refer to: A-89-73

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On April 28, 1988, at 1346, a Boeing 737-200, N73711, operated by Aloha Airlines Inc., as flight 243, experienced an explosive decompression and structural failure at 24,000 feet, while en route from Hilo, to Honolulu, Hawaii. Approximately 18 feet from the cabin skin and structure aft of the cabin entrance door and above the passenger floorline separated from the airplane during flight. There were 89 passengers and 6 crewmembers on board. One flight attendant was swept overboard during the decompression and is presumed to have been fatally injured; 7 passengers and 1 flight attendant received serious injuries. The flightcrew performed an emergency descent and landing at Kahului Airport on the Island of Maui.[1]

The damage discovered on the accident airplane, damage on other airplanes in the Aloha Airlines fleet, fatigue striation growth rates, and the service history of the B-737 lap joint disbond problem led the Safety Board to conclude that, at the time of the accident, numerous fatigue cracks in the fuselage skin lap joint along S-10L linked up quickly to form a large crack (or cracks) which resulted in catastrophic failure of a large section of the fuselage.

The Safety Board identified three factors of concern in the Aloha Airlines maintenance program. They were: a high accumulation of flight cycles between structural inspections, an extended time period between inspections that allowed the related effects of lap joint disbond, corrosion, and fatigue to accumulate, and the manner in which a highly segmented structural inspection program was implemented.

The Aloha Airlines maintenance program did not adequately recognize and consider the effect of the rapid accumulation of flight cycles. The Safety Board notes that flight cycles are the dominant concern in the development of fatigue cracking in pressurized fuselages and the accumulation of damage as a

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[1] For more detailed information, read Aircraft Accident Report--"Aloha Airlines, Flight 243, Boeing 737-200, N73711, near Maui, Hawaii, April 28, 1988" (NTSB/AAR-89/03).

result of flight and landing loads. The Aloha Airlines maintenance program allowed one and one half times the number of flight cycles to accumulate on an airplane before the appropriate inspection. The Safety Board believes Aloha Airlines created a flight-hour based structural maintenance program without sufficient regard to flight cycle accumulation.

The Boeing Maintenance Planning Document (MPD) assumed a 6- to 8-year interval for a complete D check cycle, and the Aloha Airlines D check maintenance program required 8 years to complete a D check cycle. The Safety Board believes that the 8-year inspection intervals in the Aloha Airlines maintenance program was too lengthy to permit early detection of disbond related corrosion, to allow damage repair, and to implement corrosion control/prevention with the maximum use of inhibiting agents.

Of additional concern to the Safety Board was Aloha Airlines' practice of inspecting the airplane in small increments. The Aloha Airlines D check inspection of the B-737 fleet was covered in 52 independent work packages. Limited areas of the airplane were inspected during each work package, and this practice precluded a comprehensive assessment of the overall structural condition of the airplane.

The Safety Board believes that the use of 52 blocks/independent work packages is an inappropriate way to assess the overall condition of an airplane and effect comprehensive repairs because of the potential for air carriers to hurry checks in order to keep airplanes in service. Further, the fact that the FAA found this practice to be acceptable without analysis is a matter of serious concern.

The effectiveness of Aloha Airlines inspection programs was further limited by time and manpower constraints and inadequate work planning methods. Maintenance scheduling practices utilized the overnight nonflying periods to accomplish B checks which, in reality, included portions of the C and D check items. However, since there were usually no spare airplanes in the fleet, it was obvious to both the maintenance and inspection personnel that each airplane would be needed in a fully operational status to meet the next day's flying schedule. Thus, only a few hours were available during each 24 hour period to complete B, C, and D inspection items and to perform any related or unscheduled maintenance on the airplane.

An examination of a recovered portion of the S-4R fuselage structure of N73711 indicated that the S-4R lap joint had been inspected and repaired as a result of AD 87-21-08 in November 1987. At that time, cracks were detected visually and two repairs were accomplished. Although Aloha Airlines maintenance personnel stated that an eddy current inspection of the remaining rivets in the panel was conducted to comply with the requirements of the AD, no mention of this inspection was found in the maintenance records.

Initial examination of the lap joint section between the two repairs disclosed visually detectable fatigue cracks that emanated from the fastener holes of the top row of rivets. Laboratory examination revealed the presence of many more cracks that were well within the eddy current detectable range.

Additionally, it was noted that the upper rivet row between the repairs and forward and aft of the repairs still contained the original configuration countersunk rivets.

There are several possibilities why the inspectors, when complying with the AD, failed to find the detectable crack in the S-4R lap joint on N73711, even though the area reportedly was given an eddy current inspection and two inspectors performed independent visual inspections. First, the human element associated with the visual inspection task is a factor. A person can be motivated to do a critical task very well; but when asked to perform that same task repeatedly, factors such as expectation of results, boredom, task length, isolation during the inspection task, and the environmental conditions all tend to influence performance reliability.

Another factor that can affect the human element involved in maintenance and inspection pertains to the effect of circadian rhythms on human behavior. Airline maintenance is most often performed at night and during the early morning hours; the time of day that has been documented to cause adverse human performance. Maintenance programs are most effective if task scheduling takes into account the possible adverse effects of sleep loss, irregular work and rest schedules, and circadian factors on the performance of mechanics and inspectors.

For example, compliance with AD-87-21-08 required a close visual inspection of the lap joints along S-4L and R and eddy current inspection of the upper row of lap joint rivets along the entire panel in which defects were found. This imposed considerable demands on the inspector if the results of the inspection were to be reliable. The AD required a "close visual inspection" of about 1,300 rivets and a possible eddy current inspection of about 360 rivets per panel. Inspection of the rivets required inspectors to climb on scaffolding and move along the upper fuselage carrying a bright light with them; in the case of an eddy current inspection, the inspectors needed a probe, a meter, and a light. At times, the inspector needed ropes attached to the rafters of the hangar to prevent falling from the airplane when it was necessary to inspect rivet lines on top of the fuselage. Even if the temperatures were comfortable and the lighting was good, the task of examining the area around one rivet after another for signs of minute cracks while standing on a scaffolding or on top of the fuselage is very tedious. After examining more and more rivets and finding no cracks, it is natural to begin to expect that cracks will not be found. Further, when the skin is covered with several layers of paint the task is even more difficult. Indeed, the physical, physiological, and psychological limitations of this task are clearly apparent.

Another factor that may have affected the performance of Aloha's maintenance and inspection personnel is related to the quality of support provided by Aloha management to assist these persons in the performance of their tasks. Proper training, guidance, and procedures are needed as well as an adequate working environment, sufficient aircraft down time to perform the tasks (i.e. flexible scheduling), and an understanding of the importance of their duties to ensure the airworthiness of the airplanes. Aloha Airlines training records revealed that little formal training was provided in NDI techniques and methods. The inspector who found the S-4R lap joint cracks requiring repair stated that only on-the-job training (OJT) had been provided since he became an inspector in August 1987; his training records show formal NDI training on September 17, 1987, when a 2-hour training session was given by a Boeing representative. Records indicate the inspector who provided the initial OJT had only 2 hours of formal NDI training, during the same 2-hour training session on September 17, 1987, provided by Boeing. Thus, the Safety Board is concerned about how much knowledge the inspector staff may have possessed about disbonding, corrosion, and fatigue cracking at the time that they were required to perform the critical AD inspection task. In fact, during deposition proceedings, the inspector who performed the first AD inspection on N73711 could not articulate what he should look for when inspecting an airplane for corrosion signs.

Also, Aloha's flying schedule involved full utilization of its airplane fleet in a daytime operation. Thus, the majority of Aloha's maintenance was normally conducted only during the night. It was considered important that the airplanes be available again for the next day's flying schedule. Such aircraft utilization tends to drive the scheduling, and indeed, the completion of required maintenance work. Mechanics and inspectors are forced to perform under time pressure. Further, the intense effort to keep the airplanes flying may have been so strong that the maintenance personnel were reluctant to keep airplanes in the hangar any longer than absolutely necessary.

Inadequate guidance and support from Aloha management to its inspectors was evident also when the Production and Planning department sent to the inspector's mail box, the AD and SB on the inspection requirements of the lap joints along S-4 without further review or technical comment. These documents were complicated, critical to airworthiness, and subject to interpretation as evidenced by the disagreement about its content expressed by experts at the Safety Board's public hearing. These documents needed higher level review and written guidance as to their disposition before being sent to maintenance for action. Therefore, the Safety Board concludes that Aloha's management failed to provide adequate guidance and support to its maintenance personnel and this failure contributed directly to the cause of this accident.

Because of its criticality and complexity, the Safety Board believes that the NDI maintenance function should be reviewed by the FAA with a view towards requiring formal training, skill demonstration, apprenticeships, and formal licensing and recurrent certificaton for NDI inspectors.

At the time of the accident, Aloha Airlines, like many small operators, did not have an engineering department. Some of the functions that are usually performed by engineers at large airlines were accomplished by Aloha Airlines Quality Assurance (QA) department.

The responsibilities of an airline engineering department generally include evaluating and implementing manufacturer's SBs and ADs, evaluating airplane accidental or corrosion damage, designing or evaluating repairs, establishing aircraft maintenance schedule specifications, and providing technical assistance to other areas of the airline. Another important aspect of engineering staff activities is the oversight of inspector performance and related quality assurance activites.

The condition of high cycle B-737s in the Aloha Airlines fleet with respect to lap joint corrosion, multiple repairs, and detection of fatigue cracking is an example of what can occur in the absence of regular and knowledgeable evaluations of aircraft condition by qualified engineering staff.

Aloha Airlines management could have recognized the importance of Alert SB 737-53A1039 in light of their own experience with the previous crack along the lap joint at S-10R and could have inspected all the lap joints called out in the referenced SB while they accomplished the requirements of AD 87-21-08. The same concept applies to Boeing Service Letter (SL) 737-SL-76-2-A recommending replacement of engine control cables which were recognized by Aloha as susceptible to corrosion but were not replaced.

In addition, a qualified engineer should have interpreted the lap joint AD regarding the use of oversize protruding head fasteners in the event that fatigue damage was found. More importantly, a comprehensive structural engineering and maintenance program likely would have precluded the deteriorated condition of the airplanes by evaluating and implementing the appropriate corrosion control techniques and SBs, thus preserving company assets.

An additional area of concern to the Safety Board is the extent and number of skin repairs evident on the airplane and the effect that these repairs may have on the damage tolerance properties of the original design. The accident airplane had over two dozen fuselage repairs; the majority were skin repairs using doubler patches. This condition illustrates the extent to which aging airplanes may continue to be repaired (patched) in accordance with existing manufacturers and FAA requirements.

A large repair or the cumulative effects of numerous small repairs can adversely impact the ability of the structure to contain damage to the extent necessary to meet fail-safe or damage tolerant regulations. Additionally, the structure underlying the repairs can be difficult if not impossible to inspect, which can be detrimental where fuselage lap joints are concerned. These types of evaluations are typically beyond the expertise of QA and maintenance departments and must be addressed by qualified engineering personnel.

The Safety Board believes that the continued airworthiness of airplanes as they age would be enhanced by including qualified engineers in the operator's organization. While the Safety Board recognizes that situation may be economically unrealistic for all operators, it believes that an equivalent level of safety can be achieved only by using engineering representatives from some other source. Qualified engineers could evaluate service information and airworthiness directives with particular respect to the fleet aircraft and operating conditions. The assistance of these qualified engineers may be available through an industry group or the manufacturer.

In summary, the Safety Board believes that the Aloha Airlines maintenance department did not have sufficient manpower, the technical knowledge, or the required programs to meet its responsibility to ensure the continued structural integrity of its airplanes.

Therefore, as a result of its investigation of this accident, the National Transportation Safety Board recommends that the Air Transport Association:

> Assist member air carriers to establish maintenance department engineering services to evaluate maintenance practices including structural repair, compliance with airworthiness directives and service bulletins, performance of inspection and quality assurance sections, and overall effectiveness of continuing airworthiness programs. (Class II, Priority Action) (A-89-73)

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "... to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation A-89-73 in your reply.

Also, the Safety Board issued Safety Recommendations A-89-53 through -69 to the Federal Aviation Administration and A-89-70 through -72 to Aloha Airlines.

KOLSTAD, Acting Chairman, and BURNETT, LAUBER, NALL, and DICKINSON, Members, concurred in this recommendation.

for [signature]

By: James L. Kolstad
Acting Chairman