AIR LINE PILOTS ASSOCIATION

535 HERNDON PARKWAY ☐ P.O. BOX 1169 ☐ HERNDON, VIRGINIA 20170 ☐ 703-689-2270
FAX 703-689-4370

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Mr. Thomas R. Conroy
Investigator In Charge
National Transportation Safety Board
Major Investigations Division
490 L'Enfant Plaza East. S.W.
Washington. D.C. 20594

Dear Mr. Conroy:

In accordance with the Board's rules, the Air Line Pilots Association submits the following comments concerning the accident involving Delta Air Lines (DAL) flight 1288 which occurred on July 6. 1996 in Pensacola. FL.

This submission contains ALPA's analysis of the facts surrounding the accident and is based on information obtained from the NTSB's investigation. ALPA's suggested Safety Recommendations are included.

Summary

On July 6, 1996. at 1424 Central Daylight Time. a McDonnell Douglas MD-88, operating as Delta Air Lines flight 1288. experienced an uncontained failure of the left engine during the beginning of its takeoff on runway 17 at Pensacola Regional Airport in Pensacola, Florida. Two passengers were fatally injured. One passenger sustained serious injuries and two passengers received minor injuries.

Subsequent investigation revealed that the fan hub of the number one (left) engine had failed at or shortly after initial appiication of takeoff thrust. The fan disk separated into three major portions Debris from the engine penetrated the aircraft fuselage, causing personnel injuries and severing electrical cables. resulting in loss of aircraft electrical power. This loss of electrical power was the initial cockpit indication of a malfunction.

When the engine faiiure occurred. the crew rejected the takeoff and brought the aircraft to a stop on the runway in complete compliance with Federal Aviation Regulations and Delta procedures There were no cockpit indications of any malfunction other than loss of electrical power. The initial loss of electrical power made it impossible for the flight crew to communicate either with the passenger cabin via intercom or with Air Traffic Control via radio. Before cockpit communications could be restored, a Flight Attendant (FA) initiated a passenger evacuation. When a different FA was able to reach the cockpit and advise the Captain of the situation, he instructed the **FA** *to* keep the remaining passengers on the aircraft. The passengers who remained on the aircraft, were deplaned safely via a portable stairway after about 20-30 minutes.

Post-accident metallurgical evaluation of the hub revealed a crack with two origins in a machined tierod hole in the hub. These origins were created during the manufacturing process. developed a fatigue crack. and ultimately led to the failure of the hub In addition, this metallurgical evaluation indicated that the crack had likely been present (although smaller) at the last nondestructive inspection (NDI) undergone by the hub At the time of that inspection. the hub had accumulated 12,693 cycles The inspection was 1 142 cycles prior to the failure. A review of manufacturing inspection records showed that some surface anomalies had been identified in the tierod hole. but had been determined to be within acceptable limits.

ALPA Areas of Concern

In analyzing the facts of this accident, ALPA focused on three primary areas:

- Whether there were preflight indications that could have signaled a fan hub problem
- The decision to suspend the passenger evacuation
- The process by which tan hubs are inspected when off the engine

Of these three areas, the inspection process for fan hubs is of the greatest concern.

Preflight Indications:

During the exterior preflight inspection, the First Officer (FO) noted two items which he brought to the Captain's attention. One was missing rivets on the left wing slat - an observation that clearly had no bearing on the subsequent engine failure. The other was a minute quantity of oil or a similar fluid on the accident engine bullet nose. The fluid was destroyed by the accident, so further analysis of its content and origin was not possible. However. **post** accident investigation of the engine revealed no lubricating anomalies. the fan hub is not a lubricated **part,** nor was there any connection established or implied between the fan hub failure and the engine lubricating system. Thus, neither of the noteworthy items identified by the FO during preflight can be linked. even remotely, to the subsequent fan hub failure

In spite of the fact that the pretlight observations had no bearing on this accident, it is important to evaluate the crew's actions regarding these observations for potential safety value. In both instances. the flight crew identified a situation not specifically addressed in either their training or manuals. In such instances, the flight crew must rely on experience and judgment. The FO's decision to discuss items he felt *might* be abnormal with the Captain was entirely appropriate and consistent with effective Crew Resource Management (CRM). The Captain's subsequent decision to accept the aircraft for flight was also appropnate inasmuch as neither condition posed a hazard to the aircraft. passengers, or crew. nor did they effect the airworthiness of the aircraft.

Passenger Evacuation

Analysis of the Captain's decision not to order a passenger evacuation must be undertaken with the acknowledgment that such a decision is based solely on information available ***at the time.*** The only initial cockpit indications in this accident were of electrical failure. There was nothing available to the Captain to indicate any imminent or likely hazard to the passengers. Even after the FA advised the Captain of damage and injuries, there was no indication of danger inside the aircraft that would outweigh the potential dangers associated with evacuation (for example, the injuries sustained by some passengers who evacuated on the FA's command). The passengers who remained after the initial evacuation were well forward and not likely to be subject to any psychological trauma due to the presence of casualties in the rear of the aircraft. The Captain's decision to protect the passengers from the hazards of jumping or sliding off the aircraft and of potentially being at risk from emergency vehicle movements near the aircraft was clearly in keeping with his responsibility to ensure passenger safety at all times when in his charge.

Fan Hub Inspection

ALPA believes that this accident, like all others, was the end result of a chain of events, the elimination of any one of which would have stopped the sequence of events and prevented the accident. The central issue for analysis in this accident is the fan hub manufacturing and inspection process. Some element or elements of that process must have failed, supporting a chain of events that resulted in failure of a hub in service.

In order to prevent a hub from failing in service as a result of a crack, it is necessary to **design** a hub that is not susceptible to cracks, **manufacture** a hub in such a way that crack origins are eliminated, **handle** the hub in such a way that cracks cannot be introduced during shipping, storage, or installation, or **inspect** hubs using a combination of method and frequency such that if cracks exist, they are identified before they can precipitate failure of the part.

The design of the accident hub is neither unconventional nor unique. Machined holes are used for weight reduction, balancing, and to attach the hub to other engine components. Thus, these machined holes are a necessary element of the hub's construction. The thickness of the hub is such that the required hole is relatively deep with respect to its diameter. It is neither practical nor realistic to suggest that the design of this hub (and, presumably, all similar hubs) be changed to eliminate design features that can only be achieved by incorporating machined holes.

The next area that might be changed to interrupt the accident sequence is manufacturing. As noted above, if a method could be employed that could not generate fatigue crack origins, then hub cracking would be eliminated. More realistically put, if a method could be identified that did tend to create crack origins, and that method was discontinued, then cracks would be less likely. The holes in the accident hub were machined using a coolant-channel drill (CCD) process. The CCD process utilizes a single plunge of a drill bit containing a channel through which coolant is forced in order to prevent heat buildup and to flush chips from the hole during machining. The CCD process is in contrast to the conventional bit method, which uses a multi-step plunge procedure and which employs coolant flushing from external nozzles surrounding the work area. Early in the investigation, the CCD process was suspect. However, in spite of numerous attempts by the manufacturer to replicate the failure mechanism using CCD and non-CCD methods, even using deliberately abusive machining, the CCD process was not shown to be any more likely to lead to crack formation than other methods.

Even if it were possible to design and manufacture a hub such that the likelihood of a crack formation mechanism was at or near zero, this would only affect the hub until it left the manufacturer. Neither the design nor the manufacturing process can positively eliminate the possibility of mishandling from the time the part leaves the factory until it is installed on the aircraft.

An aggressive, effective inspection process is the most realistic approach to preventing a hub from failing in service. The process must be based on the assumption that any hub may contain a crack, and must be able to detect the crack before it leads to in-service failure. Such an inspection process should include both the frequency of inspection and the type(s) of inspection employed. The current requirement for in-service inspection of fan hubs does not ensure that every hub is inspected even once during its service life. Inasmuch as hubs may have identified anomalies that are judged insignificant at manufacture. a periodic inspection requirement to validate that original judgment is critical. **ALPA believes that the absence of a required inspection schedule for every fan hub is inadequate.**

Two distinct failures of the inspection process are evident in this accident. The accident hub was subject to a blue etch anodize (BEA) inspection during manufacture. This inspection identified anomalies that were compared with a standard and judged acceptable. In retrospect. that determination was clearly in error. Thus, either the method used was flawed, the execution of the procedure was incorrect. or the standard was inadequate Later in its service life, the accident hub was subject to a fluorescent penetrant inspection (FPI) that did not detect any defects. Again in retrospect, that determination was also incorrect In the case of the FPI. no standard of acceptability was employed because no defect was identified. The failure of the FPI process to identify a crack must then be due to either method or execution. **ALPA believes inspection methods in current use are inadequate in several areas:**

- <u>Lack of an objective standard</u>
  The BEA and FPI processes both require an inspector to make a subjective evaluation of what he or she sees. In the case of the BEA method, the inspector compares the part in question to a photograph which is the standard. Based on that comparison, the inspector must determine if an anomaly exists. This relies on a presumption that all identifiable anomalies have been photographed. that the photographs are clear and unambiguous, and that the inspector can make an accurate comparison of the actual part with the photograph. If an anomaly is identified. the inspector must determine if it is significant. Again, a subjective set of standards comes into play, ultimately relying on the inspectors judgment and experience to make the correct determination. In the FPI process, it is up to an inspector to visually identify the fluorescence of the dye in the crack and use his or her judgment to discriminate between actual cracks and dye that has simply adhered to areas of the part or background (“false positives”). It is unrealistic to assume that even the best professional judgment is 100% accurate. so it is inevitable that the inspection process will allow some flaws to go undetected This reinforces the need for periodic reinspection.

- <u>Susceptibility to error</u>
  The FPI process consists of several steps, each of which is subject to a variety of human errors and process inadequacies. **All** must nevertheless be performed properly for the final

inspection to be accurate While the method may be perfectly fine for finding cracks on the exposed surfaces of small parts. its effectiteness diminishes as the focus area becomes less accessible. or if the part is cumbersome and must be maneuvered extensively to ensure a complete inspection. In the case of the fan hub. both limitations come into play. Thus, one of the most notable limitations of the process is its lack of suitability to identify cracks in deep holes in large. heavy parts.

The first step in preparing a part for FPI is a thorough cleaning. Without such a cleaning, the subsequent application and use of penetrant dye may be ineffective. However. even though the inspectors are skilled, experienced technicians. the cleaners are typically entry level workers. These workers may not have a complete understanding of the potentially hazardous consequences of an improperly cleaned part. Even if the part is well cleaned. potential errors can be introduced in this step if the residue from the cleaning process (either water or plastic media blasting) is not completely removed. After cleaning, the part is dipped in penetrant dye. it must be maneuvered such that the dye flows to every area and surface, no matter how well hidden. It is then rinsed. The rinsing must be "just enough" to remove excess dye without removing dye in cracks. Then the part is dipped in emulsifier *to* make the dye water-soluble and further aid in the removal of excess dye. Again. the technician must ensure that every area is covered. The part is again rinsed "just enough" and dried. The drying, too. must be complete, and again relies on a technician's ability to ensure that every recess, no matter how deep or inaccessible. is dry. Finally, a dry developer powder is sprayed on the part to draw the dye out. making the crack location visible at the surface. For a crack to be identifiable, dye must penetrate into the crack, not be removed by the rinsing, and then be drawn out by the developer. Throughout all these processes, the part must be maneuvered such that every surface and recess is placed in contact with the proper amount of the appropriate material. Finally. assuming that all cracks have dye in them, the entire **part** must be made viewable. To do this. the inspector must use a combination of hand-held and fixed ultraviolet lights. mirrors. and magnifiers, maneuvering his or her head. hands. and the part in such a manner that every surface and recess is viewed.

- Lack of effective quality control

  The number of variables in the FPI process is considerable Fluid temperature and chemical content, application pressure, distance from the part. and duration of exposure are all critical. Some of these variables (e.g. fluid temperature and chemical content) are periodically checked for conformity to established standards. Others (e.g. duration of exposure) are left to the inspector or processor to measure correctly at the time. In any case, if **an** "out of tolerance" condition is identified in any of the variables, there is no process by which inspected parts are recalled and reinspected. The nature of the process makes it incumbent on the inspector to identify suspicious indications and take action. If no suspicious indication is identified. there is no subsequent check employed to **verify** the absence of a defect. Ultimately, if an inspector sees a part with no defects. there is no way to determine if the part is, in fact, defect free, or **if** one of the several steps in the process was improperly performed.

Recommendations

ALPA offers the following recommendations to correct deficiencies noted above:

1. Industry should expand the use of alternatives *to* FPI (e.g. eddy current inspection) for inspection of holes and other inaccessible areas of parts.
2. Inspection methods and standards should be refined with the ultimate goal of eliminating subjective standards.
3. The FAA should develop inspection criteria based on the assumption that crack origins and similar manufacturing defects cannot be eliminated. Thus. inspection intervals must be such that potentially catastrophic defects can be identified prior to failure.
4. Inspection methods that rely heavily on subjective criteria and human operator judgment must be part of a "fail safe" process of checks and balances. Such checks must ensure that no single failure of an individual to perform his or her task can lead to a catastrophic event.

ALPA appreciates the opportunity to have participated as a party to the investigation and hopes the above comments and recommendations will be of assistance as the Board concludes its investigation.

Sincerely,

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David M. Jones
Air Line Pilots Association
Party Coordinator

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cc: National Transportation Safety Board Members
Mr. Bob Henley - FAA
Mr. Jim Anderson - Delta
Mr. William C. Steelhammer - McDonnell Douglas
Mr. James A. Sunamoto - Pratt & Whitney
Mr. Richard C. Slade - Pensacola Regional Airport
Volvo Aero Corporation