NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

December 21, 1995

ADDENDUM A - POWERPLANT GROUP FACTUAL REPORT

DCA-95-MA-054

A. ACCIDENT

Location:	Carrollton, Georgia
Date:	August 21, 1995
Time:	1250 Eastern Daylight Time
Airplane:	Atlantic Southeast Airlines, Embraer EMB-120, N256AS

B. POWERPLANT GROUP

Jerome D. Frechette Group Chairman	Aerospace Engineer, Airworthiness National Transportation Safety Board
Malcolm Brenner, PhD.	Human Factors Specialist National Transportation Safety Board
Jim Wildey	National Resource Specialist Aerospace Engineer, metallurgy National Transportation Safety Board
Frank Walsh	Aerospace Engineer Engine Certification Office Federal Aviation Administration
Cee D. Smallwood	Technical Support Technician, Powerplant Atlantic Southeast Airlines
Capt. John T. Rice	Chief Accident Investigator Atlantic Southeast Airlines Airline Pilots Association
Manual S. Monteiro	Manager, Technical Liaison/Safety Embraer Aircraft Corporation

Stuart C. Browning Sr. Service Engineer / Group Leader
Commercial Customer Service
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C. SUMMARY

On August 21, 1995, at about 1253 eastern daylight time, an Embraer EMB-120RT, N256AS, airplane operated by Atlantic Southeast Airlines (ASA) crashed after departing the Atlanta Hartsfield International Airport (ATL), Atlanta, Georgia. The flight was a scheduled passenger flight carrying 26 passengers and a crew of three operating under the provisions of Title 14 Code of Federal Regulations (CFR) Part 135. The flight was operating in accordance with instrument flight rules (IFR). While climbing through 18,000 feet, the flightcrew declared an emergency and initially attempted to return to Atlanta. The pilots advised they were unable to maintain altitude and were vectored toward West Georgia Regional Airport, Carrollton, Georgia, for an emergency landing. The airplane crashed while en route to Carrollton. The airplane was destroyed by impact forces and postcrash fire. The captain and seven passengers received fatal injuries.

Following the field portion of the investigation, the Safety Board forwarded a list of questions and a request to interview the Designated Engineering Representative (DER) of the 14RF-9 propeller design, to United Technologies, Hamilton Standard. Additionally, the Safety Board requested to interview the Certifying Engineer from the Federal Aviation Administration, Engine and Propeller Directorate, Burlington, Massachusetts. The questions the Safety Board forwarded to Hamilton Standard concerned the design, repair, and inspection of the 14RF and 14SF propellers, the normal blade forces, vibratory modes and stress during operation, the fracture mechanics of a blade failure, the load imbalance following a blade failure, the flight test program, the inspection status of Telegraphic AD T95-18-51 and Priority Letter AD 95-18-06R1, application differences for this propeller, and any other engineering effort currently not known to the NTSB surrounding the investigation following the ASA EMB120 accident of August 21, 1995, Carrollton, Georgia. The interviews concerned the involvement of the DER and the Certifying Engineer in the 14RF-9 propeller blade design and repair process.

The Powerplant Group reconvened on September 13 and 14, 1995, at Hamilton Standard, Windsor Locks Connecticut where engineers provided responses to questions by the Powerplant Group, and where the interviews with Mr. Stuart Browning, DER Hamilton Standard, and Mr. Frank Walsh, FAA, Engine and Propeller Directorate were conducted. The responses from Hamilton Standard and the interviews are summarized in this report.

D. SUMMARY OF THE PRESENTATION

The following is the summary of the presentation. Attachment A ia a copy of the slides provided to the Group by Hamilton Standard personnel.

1.0 PROPELLER BLADE DESIGN

The Safety Board requested a brief history of the Hamilton Standard 14RF, and 14SF propellers with discussion about the operation and the development of the design, material, and manufacturing. The Group learned that the 14RF, 14SF, and 6/5500/F propeller blades were the first blades of this type to be developed. The aluminum alloy spar is the main load carrying member and incorporates a taperbore in the shank for weight reduction and balance weight installation. The taperbore on the 14RF blade has two different shaped designs, one is symmetric and is known as the M style, and the second has a bellmouth and is known as the N style and are either shotpeened and unshotpeened. Both taperbore designs are stuffed with a measured amount of lead wool for blade balancing. The operator has the option of adding sufficient balance lead to an N style blade to make it weigh as much as an M style blade. A cork was inserted for lead wool retention; however, it was subsequently eliminated in April, 1994, because it was found to be a source of chlorine in the taperbore.

The Group learned that the 14RF, 14SF and 6/5500/F propeller assemblies (Attachment A, page 9) are installed on seven types of aircraft, operated by 143 operators, on 1,343 aircraft, for an industry total of approximately 15,222 blades as of September 13, 1995. Also, the 14RF, 14SF and 6/5500/F propellers vary in diameter and operating rpm settings. The following table summarizes the different installations, diameters and maximum operating rpm's of the 14RF, 14SF, and 6/5500/F propellers:

AIRCRAFT	PROPELLER	DIAMETER	ENGINE	MAX RPM
EMB 120	14RF-9	10.5 feet	PWC 118	1,300 rpm
CN 235	14RF-21	11.0 feet	CT-7	1,384 rpm
SAAB 340	14RF-19	11.0 feet	CT-7	1,384 rpm
DHC 8-100	14SF-7	13.0 feet	PWC 120	1,200 rpm
ATR 42	14SF-5	13.0 feet	PWC 120	1,200 rpm
ATR 72	14SF-11	13.0 feet	PWC 124	1,200 rpm
DHC 8-300	14SF-15/23	13.0 feet	PWC 124	1,200 rpm

CL 215/215P	14SF-17/19	13.0 feet	PWC 120	1,200 rpm
ATP	6/5500/F	13.75 feet	PWC 126	1,200 rpm

2.0 AERODYNAMIC LOADS ON THE PROPELLER

The Safety Board requested an explanation of the forces of which a propeller is subjected during operation (Attachment A, pages 10 thru 14). The Group learned that Hamilton Standard determined the loads to which the propeller was subjected during normal operation for proper blade and propeller design; however, a reexamination of the propeller loads was conducted following the recent blade failures.

The Group learned that the average aerodynamic loads acting on a propeller blade during operation steadily increases from near zero at the blade root to a maximum at about 80% of blade span. Beyond approximately 90% of blade span the aerodynamic load drops to nearly zero. It was explained that although the twist of the blade maintains a constant angle of attack along the blade span, the aerodynamic load on the blade increases with an increase in radius because the speed at which the blade is moving increases. The thrust load drops beyond about 90% span because as you approach the tip the pressure difference between the blade face and blade back equalizes around the tip giving way to a tip vortex.

The Group also learned that the aerodynamic loads on a propeller can be cyclical. The frequency of these cyclical aerodynamic loads are multiples of propeller rpm and is one of the sources of excitation energy for blade vibration. High vibration and consequently high stress can result when the excitation frequency from a cyclical aerodynamic load matches the natural or resonant frequency of the blade. The propeller is designed to limit the amount of exposure to this condition.

The frequency of the first cyclical aerodynamic load is 1P and equals propeller rpm, that is, one cycle per revolution. Therefore any variation in propeller rpm varies the 1P frequency. The 1P cyclical aerodynamic load is a function of air in-flow angle-of-attack to the propeller and is most pronounced during takeoff where aircraft angle of attack, propeller rpm and blade loading are high. Under these conditions there is a component of airflow below the propeller's axis of rotation that increases the angle of attack of the descending blade and decreases the angle of attack of the rising blade. As the relative angle of attack varies with each revolution so does the blade load.

A design feature of some airplanes incorporates a nose-down installation angle (down tilt) of the engine relative to the aircraft wing. Down tilt reduces the 1P cyclical aerodynamic load during high gross weight takeoffs and climb. Conversely, downtilt can increase the 1P loads during cruise and during low gross weight cruise. Additionally, some airplanes incorporate a nose-in installation angle (toe-in) of the engine relative to the aircraft wing.

The frequency of the second cyclical aerodynamic load is 2P and acts on all propeller blades twice per revolution. The blade senses the wing leading edge as the blade passes the leading edge twice per revolution. The 2P load is always present. During forward flight, the 2P loads are negligible; however, it is most pronounced during operation in a tailwind or quartering tailwind condition. Under tailwind or quartering tailwind conditions, it was explained that the presence of the wing interferes with the inflow of air to the propeller, imparting an additional variation to the aerodynamic load as each blade passes the wing leading edge. The warning placard on the EMB120 instrument panel which states, "AVOID Np ABOVE 65% STATIONARY, CROSSWIND," was reportedly placed there to limit operation where 2P aerodynamic loads are more pronounced.

The third, fourth, fifth and so on "P" orders of cyclical aerodynamic loading are multiples of propeller rpm and as such, each P order of cyclical aerodynamic loading has an associated frequency. It was learned that the effects of these higher order loads are small, and diminish as P order increase.

The Group learned that the stress survey conducted during the development of the 14RF-9 blade confirmed predicted stresses (Attachment A, page 15). The calculated blade steady stress distributions are caused by centrifugal tension, aerodynamic loads and inertial bending loads. The steady stress calculated from beam theory indicates that the maximum steady stress in the 14RF-9 spar is approximately 4,200 pounds per square inch (psi) at the blade root, which increases to approximately 10,000 psi from approximately 10 to 30 inches, then steadily reduces to approximately 2,000 psi at 60 inches. There is a slight increase in the steady stress at the tip because of the reduced spar cross sectional area at the lightning strip.

The calculated vibratory stress is caused by cyclic airloads and inertial response, magnified by the proximity of a resonant frequency to an exciting P order frequency. The vibratory stress follows a similar trend as the steady stress at each station; however, the vibratory stress peaks out at approximately 5,500 psi with no increase at the tip. The predicted cyclic stresses are verified by flight test for each propeller installation prior to issuance of the type certificate.

The Group learned that a new, more detailed flight test was to be conducted by the FAA and Hamilton Standard as a result of the recent blade failures. The plan is to investigate blade to blade variability, left engine to right variability, aircraft to aircraft variability, and ground taxi effects. The United Technologies Canada (UTC) airplane is the planned test bed. Data reduction is planned to be finished by mid October and forwarded to Embraer to determine the need for additional testing.

3.0 PROPELLER MODES OF VIBRATION

The Safety Board requested an explanation of the reactionless mode of vibration. The Group learned that all propellers have a tendency to vibrate when there are sufficient excitation loads, and that most vibration modes are driven by the natural or resonant frequency of the blades (Attachment A, pages 16 thru 19). Hamilton Standard designs the propeller such that resonant frequencies do not coincide with the P order frequencies; however, following the recent blade failures, Hamilton Standard conducted a reevaluation of the coincidence of resonant frequencies and P order frequencies.

There are three components of blade movement whether due to vibration or load, whether cyclical or steadystate. They are movement perpendicular to the chord-line or flat-wise direction, movement parallel to the chord-line or edge-wise direction, and movement about the blade longitudinal axis or torsion. There are corresponding resonant modes in each of these primary directions. Because the blades are twisted, these primary modes are accompanied by lesser movement in the other directions. For a propeller at a flat pitch setting, movement in the flat-wise direction near the tip moves the blade fore and aft "out of the plane" of rotation. As the radius is decreased, flat-wise tip movement is accompanied by some degree of edge-wise or in plane movement near the blade root. Also, a small amount of torsion accompanies this movement. The resultant movement is the vector addition of the movements at each individual blade station. When the blade is at other pitch angle settings, the flat-wise and edge-wise movement rotates accordingly.

A resonant frequency of a propeller blade is a function of blade stiffness, mass distribution and to a lesser extent, retention stiffness. During vibration in the first flat-wise or first edge-wise mode, the blade moves in the same direction, perpendicular to the chord or parallel to the chord with bending all along the blade. Vibration in the second flat-wise and second edge-wise mode is characterized with a node point (point of near zero deflection) at about 3/4 span with inboard and outboard opposing motion. Therefore, the opposing motion is maximized at about 50% blade span and peaks at the tip. Higher orders of vibration, have an associated higher number of nodal points and points of maximum deflection. Each order of vibration has an associated frequency, called a resonant frequency.

The Group learned that when the excitation frequency (P order) approaches one of the blade resonant frequencies, vibration of the blade and the propeller will result and depending on the mode, vibration of the engine may result. Depending on the P order of excitation and the number of blades in the propeller, three types of propeller vibration can result; whirl, symmetric, and reactionless vibration modes. The propeller system is designed to operate such that the P orders of excitation do not coincide with the resonant frequencies of the propeller blade in the allowable rotational speed range.

In the following description of propeller vibration in a four bladed propeller, a "blade pair" are blades opposite each other, relative to the hub and the "other blade pair" are the blades at 90 degrees.

The "whirl" mode, associated with a 1P load, is when blades in a blade pair vibrate 180 degrees out-of phase relative to each other, that is, the vibrating blade at 12 o'clock is exactly out-of-phase with the blade vibrating at 6 o'clock. The blades in the other blade pair are also 180 degrees out-of-phase relative to each other, but 90 degrees relative to the other blade pair. This 1P whirl is a special case because the resultant load applies a constant not-gyrating moment to the static structure. Higher P orders of whirl mode tend to cause the engine to gyrate or move around the axis of rotation.

The "symmetrical" mode is when the both blades in a blade pair are vibrating in phase relative to each other and are vibrating exactly in phase with the other blade pair. Symmetrical mode is also described as the "umbrella" mode because the movement of the propeller blades is similar to the spokes of the umbrella when repeatedly opening and closing the umbrella. There is a torsional symmetrical mode too, where the movement of the blades would resemble the spokes of the umbrella if the shaft were repeatedly twisted back and forth. During vibration in the symmetric mode, the vibratory motion is additive at the hub and the engine tends to vibrate fore and aft, parallel to the axis of rotation.

The "reactionless" mode is when both blades in a blade pair are vibrating in phase relative to each other; however, they are vibrating exactly out-of-phase with the other blade pair. That is, the vibrating blade at 12 o'clock which is exactly in phase with the vibrating blade at 6 o'clock, however, it is exactly out-of-phase with the vibrating blades at 3 and 9 o'clock. During vibration in the reactionless mode, the vibratory motion is canceled at hub and the engine has no tendency to vibrate.

The 14RF-9 propeller, which is a four bladed propeller, will vibrate in the whirl mode if the 1st flat-wise resonant frequency is matched to either the 1P, 3P, and 5P, excitation frequency. The 14RF-9 propeller will vibrate in the reactionless mode if the 1st flat-wise resonant frequency is matched to the P-2 excitation frequency.

4.0 DIFFERENCES OF 14RF-9 VS OTHER NON-14RF-9 APPLICATIONS

The Group learned that the non-14RF-9 Hamilton Standard commuter propeller operates at propeller rpm settings such that the resonant frequencies associated with the 1st flat-wise and 1st edge-wise vibration modes are away from the 1P, 2P and 3P excitation frequencies (Attachment A, page 18 and 19). It was explained that although the 2P excitation frequency matches the 1st flat-wise resonant frequency in the non-14RF-9 models at approximately 50% to 55% rpm, this condition is transitory and only takes place during engine start and therefore is considered inconsequential. It is considered inconsequential because engine power is very low and the propeller only accumulates a few cycles per flight.

The Group learned that the 14RF-9 propeller is different than other installations. The 14RF-9 propeller on the EMB120 uses the ground idle rpm range from 50% to 65%, and a flight rpm range from 80% to 100%. The 50% ground idle was made available to reduce cabin noise. To accomplish this, Hamilton Standard designed the 14RF-9 propeller such that the 1st flat-wise and 1st edge-wise resonant frequency bands cross over the 2P and 3P excitation frequency bands between the ground and flight rpm ranges at about 70% propeller rpm. This design places the crossover point of the 1st flat-wise resonant frequency and the 2P excitation frequency to within about 5% of the 65% rpm ground operating condition. As a result, the ASA EMB 120 Pilot Operating Handbook (POH) states that with the aircraft stationary the propeller should not be operated above 65% Np, except for short durations. Also, for longer duration static runs, the maintenance manual states that for operation above 65% the aircraft should be headed into the wind to within + and - 45 degrees, if the wind exceeds 10 knots.

The Group learned that Hamilton Standard is concerned that the 14RF-9 propeller installed in the EMB120 could potentially vibrate in the 1st flat-wise mode (reactionless) during ground operations at 65% rpm in a tailwind or quartering tailwind, where the 2P excitation is most pronounced.

5.0 PROPELLER BLADE FRACTURE MECHANICS

The Safety Board requested an explanation of the fracture mechanics of the blade taperbore failures understood thus far by Hamilton Standard. The Group learned that there had been three blade fractures where a crack formed on the inside of the taperbore and propagated outward until instantaneous failure.

It was learned the Hamilton Standard studies the fracture mechanics of each blade failure to determine why and how rapidly the crack initiates, why and how rapidly the crack propagates, and how much time does it take for the crack to reach critical length and instantaneous failure. The cyclical stresses to which a blade is subjected over one flight is defined as one cycle. A flight includes a takeoff, the climb, cruise for differing amounts of time, the approach, and landing with the application of reverse thrust.

Crack initiation for the recent taperbore blade failures is believed to take place when a corrosion pit of a certain size is subjected to cyclical stresses of a certain amount over a number of cycles. Therefore, a determination of the formation and growth rate of the pit, and the size a pit must become is critical for crack initiation predictions. If an accurate prediction of the pit formation, pit growth and pit size, and the cyclical stresses to which the pit is subjected during normal operation can be made, then an accurate prediction of how many flights before crack initiation take place can be made.

Crack propagation for this type failure takes place when a crack is subjected to cyclical stresses. Examination of the crack surfaces revealed curved marks surrounding the crack initiation points. These marks are called beach marks or striation marks and are formed as the crack propagates. The crack advances an incremental amount as a function of the cyclical stress, this is called "fatigue". The crack propagates radially outward in a chordal plane to the outside face surface of the blade spar. This area is called Zone I. After reaching the outside face surface of the blade spar, the crack then propagates in the opposite direction, from the outside face surface to the blade back. This area is called Zone II.

As the crack in Zone II enlarges, the spar eventually gives way and fails instantaneously. Examination of the fatigue area of the recent blade failures, indicate that Zone II grows to approximately 75% of the spars crossectional area before instantaneous failure.

The striation spacing on the blade fatigue surface is measured at multiple locations. Attempts are made to correlate striation spacing in each zone and how striation spacing varies within each zone. Striations are difficult to count and striation spacing is difficult to measure in all metallurgical examinations because the spacing becomes infinitesimally small. If the striation spacing in the fatigue area can be correlated to the number of cycles to which the blade was subjected, then an accurate prediction of how many flights before blade failure can be made.

It was learned that Hamilton Standard could not accurately correlate striation counts or striation densities to cycles as currently defined for the three blade failures to date.

6.0 PROPELLER BLADE INSPECTION AND REPAIR

The Safety Board requested an explanation of the inspection and repair history of the 14RF propeller preceding the accident of August 21, 1995 Carrollton, Georgia. The Group learned that following the InterCanadian ATR 42 blade failure of March 13, 1994 and the Nordeste EMB120 propeller blade failure of March 30, 1994, that a one-time inspection of all blades was required. Blades that did not pass UT inspection were removed from service and sent to Hamilton Standard for review. Hamilton Standard inspected the taperbores of the blades and discovered that although no cracks were found, mechanical damage existed in excess of what engineers thought acceptable. Hamilton Standard believed the mechanical damage in the taper bore was a result of the installation and removal of the balance lead.

As a result, repair PS960 was developed for use within Hamilton Standard to locally blend mechanical damage, perform an ultrasonic inspection, mark the blade and return to the blade to service. The repair limited the material removal in the taper bore to a maximum of 0.010 inches on face side and 0.020 inches on the remaining 270 degrees of circumference. The blended area required a surface finish of an RMS standard 63 followed by the application of an Alodine chemical film. The blade was then to be rebalanced and the cork reinstalled. A blend repair of mechanical damage in accordance with PS960 was considered terminating action with no further inspection required of the taperbore.

Examination of the InterCanadian blade revealed corrosion with chlorine deposits inside the taperbore. Examination of the cork revealed chlorine which was used to bleach the cork. As a result, on April 18, 1994, PS960A eliminated the cork and proseal was used instead.

The Group learned that the taperbore repair procedure was further developed to include shotpeening all the blades and reaming and shotpeening those blades with damage beyond local area blend repair limits. The Component Maintenance Manual (CMM) was revised to include the taperbore repair procedure and was subsequently released on September 1, 1994. The CMM superseded PS960/960A.

An ultrasonic inspection technique was developed to disclose cracks in the taperbore on the face side and camber side of the blade. The ultrasonic inspection kit included a calibration block with a simulated crack. The ultrasonic sensor is placed on the calibration block and slid over the simulated crack to calibrate the deflection of the signal on Cathode ray tube (CRT) to 80% of full scale height (FSH). Following calibration, the sensor is placed on the face side and camber side of the blade within the confines of a template and slid up and down the spar to inspect the taperbore. Signal deflections greater than 50% of FSH on the face side and 80% on the back side are considered unacceptable and warrant further inspection. All signal deflections above 40% are recorded.

An eddy current inspection procedure is reportedly under development. Laser is reported considered good for pits but not for cracks. X-ray is currently not under development.

The following table lists the Hamilton Standard repair documents, FAA airworthiness directives, NTSB recommendations, date of issue, why issued, and a brief summary of what action they accomplished:

DOCUMENT	DATE	WHY ISSUED	ACCOMPLISHMENT
PS960 (Process Standard)	Apr 8, 94	Blades inspected after InterCanadian	Visually inspect, locally blend mechanical damage,

		incident Mar 13, 94 and Nordeste EMB-120 incident Mar 30, revealed mechanical damage in taper bore.	ultrasonic inspect, mark, and return to service 14RF and 14SF blades.
14RF-9-61-A66 (Service Bulletin)	Apr 18, 94	InterCanadian incident Mar 13, 94 and Nordeste EMB120 incident Mar 30.	One time ultrasonic inspection of all 14RF-9 blades, (other S.B.'s covered other blades). H.S. coordinates world wide inspection program with about 33 inspectors.
PS960A (Process Standard)	Apr 18, 94	Chlorine rich deposits discovered in taper bore in InterCanadian blade.	Perform PS960, also remove cork and replace with proseal. Mark PS960A
AD 95-05-03 (Airworthiness Directive)	Apr 22, 94		Require S.B. 14RF-9-61-A66 on all 14RF and 14SF blades
14RF-9-61-A69 (Service Bulletin)	Aug 5, 94		Repeat ultrasonic inspections at 1,250 cycle intervals on unpeened blades, also remove cork if installed.
C.M.M. revision 7 (Component Maintenance Manual)	Sep 1, 94	Supersede PS960A, expand level of repairable damage and release process to authorized repair stations.	Improved taperbore cleaning and inspection process, measure damage, repair and shotpeen as as required, balance, mark and return to service.
14RF-9-61-A69 Revision 1 (Service Bulletin)	Oct 5, 94	Increases affected blade population of unshot-peened blades.	Same as S.B. 14RF-9-61-A69
AD 95-05-03 (Airworthiness Directive)	Mar 23, 94		Require S.B. 14RF-9-61-A69 and A69 Rev 1 on all effected blades.
14RF-9-61-70	Aug 29, 94	Option for A69	Inspection of taperbore using

			borescope, mold transfer material. A photograph was included for improved identification of corrosion damage.
A-95-81 thru 83 (NTSB Recommendation)	Aug 25, 95	ASA EMB120 accident of Aug 21, 95, Carrolloton Georgia, where blade previously repaired under PS960A fractured in flight.	Recommend immediate ultrasonic inspection on blades cited in AD 95-05-03, conduct vibration and load survey on EMB120 aircraft, and review overhaul and inspection requirements to include shotpeened blades.
AD T95-18-51 (Telegraphic Airworthiness Directive)	Aug 25, 95		Reinspect within 10 cycles all 14RF & 14SF blades previously ultrasonic inspected IAW AD 94-09-06 or AD 95-05-03 and removed from service due to crack indications. Blades removed per this AD may not be returned to service.
14RF-9-61-A85 (Service Bulletin)	Aug 28, 95		Ultrasonic inspect at 1,250 cycles or within 50 cycles if more than 1,250 cycles and reinspect at 1,250 cycle intervals all 14RF-9 blades.
AD 95-18-06 (Airworthiness Directive)	Aug 28, 95	Supersedes T95-18-51	Reinspect within 10 cycles all 14RF & 14SF blades previously ultrasonic inspected IAW AD 94-09-06 or AD 95-05-03 and removed from service due to crack indications. Blades removed per this AD may not be returned to service.
AD 95-18-06R1 (Airworthiness Directive)	Aug, 30, 95	Supersedes T95-18-51 and AD 95-18-06	Perform AD 95-18-06; however, inspect all other unshotpeened blades.

7.0 STATUS OF THE TELEGRAPHIC AD AND PRIORITY LETTER

The Safety Board requested the status of Telegraphic TAD 95-18-51 and priority letter AD 95-18-06 R1. The Group learned that approximately 2/3 of the blades manufactured were originally unshotpeened blades and of the 27% unshotpeened blades had been inspected as of September 14, 1995, and approximately 5% of those blades had ultrasonic indications. Additionally, as of September 14, 1995, 30.4% of the shotpeened blades which represents the remaining third of the blade population, had been inspected thus far and approximately 4.9% with ultrasonic indications. The total population of unshotpeened and shotpeened blades was 15,222 blades. Hamilton Standard indicated that the percentage of blades with ultrasonic indications is expected to decrease by approximately 2% as the percentage of inspected blades increase.

Examination of all blades removed from service and sent to Hamilton Standard due to an ultrasonic indication in accordance with Telegraphic AD T95-18-51 or AD 95-18-06R1, as of September 14, 1995 did not reveal any cracks.

8.0 INTERVIEWS

On September 13, 1995, Mr. Stuart Browning, Senior Service Engineer and Designated Engineer Representative (DER), Hamilton Standard Corporation, and Mr. Frank Walsh, FAA, Engine and Propeller Directorate were interviewed by Malcolm Brenner, NTSB Human Factors Specialist and the Powerplant Group at Hamilton Standard headquarters at Windsor Locks, Connecticut. The following is a summary of the interviews conducted at Hamilton Standard:

8.1 STUART BROWNING

Mr. Browning was hired by Hamilton Standard on September 11, 1978, following his completion of a B.S. degree in Astronomy from the University of Massachusetts, where he obtained a strong physics and mathematics background. Also, in January 1987, he completed the University of California, aircraft accident investigation course, and in December of 1990, competed his Masters of Business Administration at the University of Hartford, Hartford, Connecticut. He has 18 years of engineering experience which included a 5 year roving assignment providing training on propeller systems for performance and maintenance including the blending of aluminum propeller blades. He was hired as a field representative in the propulsion division, and has remained in the propulsion division.

Mr Browning has worked closely with other DERs, other company DERs and with domestic and foreign regulatory authorities on numerous propeller systems. Mr. Browning interacts with most people in the propeller division including the senior management as well as two Presidents of Hamilton Standard. He also provides interpretations regarding FAA compliance on new and existing products.

Mr. Browning said the aircraft industry was exciting, that he enjoyed working for Hamilton Standard. He liked that the company was international, and he thought the people were interesting, world travellers. However, product support could be frustrating.

In October, 1992, Mr. Browning was appointed a DER in propellers systems by the FAA. As DER, his responsibilities included reviewing the documentation, proposed repairs, and proposed engineering changes for compliance with the Federal Aviation Regulations (FAR). The DER designation is reviewed and reappointed annually by Hamilton Standard as well as the FAA. As the DER, Mr. Browning manages the expertise of the company staff. According to Mr. Browning, the DERs responsibilities represented 20% to 30% of his workload, primarily in technical publications. Mr. Browning had been involved in about thirty PS actions during his career with the company, with about ten of these as a DER. Within Hamilton Standard there are seven DERs.

Under an agreement with the FAA, Engine and Propeller Directorate, Burlington, Massachusetts, the DER has the authority to approve engineering changes, repairs, service bulletins and maintenance manuals. The FAA retains approval authority for changes that affect critical parts or single point failure components. Additionally, incidents in the field required a report to the FAA within 48 hours.

Mr. Browning interfaces directly with Mr Frank Walsh, the Certifying Engineer in the Burlington Office of the FAA. Mr. Browning said Mr. Walsh was usually accessible, and that he kept him informed about procedural and technical issues. Mr. Browning confided in Mr. Walsh and spoke by telephone about once per week. Mr. Browning also said that Mr. Walsh was very knowledgeable and that there were no difficulties discussing technical issues with him. Mr. Browning could not recall having any disagreements with Mr. Walsh.

Following the failure of the first two blades, the concern about blade failures led to the development of the ultrasonic (UT) inspection procedure and the subsequent inspection of all the Hamilton Standard commuter type blades. The UT procedure was intended to reveal cracks in the blade taperbore. Service Bulletin A66 was released which defined the UT inspection procedure and required the one-time inspection of all blades. During the inspection, four hundred ninety (490) blades out of approximately 15,000 blades worldwide, including the ASA accident blade, failed UT inspection and were returned to Hamilton Standard for further examination. Following the release of Service Bulletin A66 numerous blades were returned to the facility, especially in the May/June time frame.

With the release of Service Bulletin A66, Hamilton Standard offered a video to all operators on the bulletin mailing list. Also, following the release of A70, Hamilton Standard provided a laser color picture of corrosion with the instruction to return blades with corrosion in the taperbores to a repair facility. The inspection procedure was only for unshotpeened blades. The operators with unshotpeened blades were provided the option to repeat the ultrasonic inspection, do visual inspection in the cork area, or return the blade to a repair facility.

During the investigations of the first two blade failures corrosion pits were discovered in the taperbores believed to be the initiation points of the fatigue crack. Additionally, mechanical damage, more prevalent than corrosion, was discovered in many of the blades taperbores and was considered unacceptable by Hamilton Standard. The blades with mechanical damage were being sidelined for lack of a repair procedure, as a result, PS960 was developed to safely return the blades to service.

The PS960 as it was originally written defined a blend repair procedure for mechanical damage inside the taperbore and was not intended to find cracks. The repair was developed for use within Hamilton Standard, in advance of revising the Component Maintenance Manual. Also, the Hamilton Standard, Rockhill facility was involved in developing the repair procedure. To aid the Technicians with PS960, video tapes and pictures of corrosion were provided.

Mr. Browning said the FAA provided input on fracture analysis and non-destructive techniques for PS960. The FAA approved the data for PS960 because the blade was considered a critical component, and the FAA requested that the repair work be accomplished only at Hamilton Standard.

Mr. Browning's role in the development of the PS960 was to ensure the analysis was diligent, the instructions were clear, that the procedure could be properly performed, and compliant with the applicable FARs. Mr. Browning was in contact with the FAA several times per week during the development of PS960, and provided additional data if needed; however, Mr. Browning believed that the repair was further developed during the daily conference calls between the Windsor Locks facility and the Rockhill facility of which he was not party.

Mr. Browning believed that corrosion pitting initiated the cracks and not mechanical damage, and therefore the mechanical damage could be safely blended, and that PS960 adequately defined the blend repair procedure. Additionally, PS960 also required a UT inspection following any blend repair ensure no UT crack indications remained and to eliminate a second UT inspection in the field.

Mr. Browning personally observed corrosion inside the taperbore from cut-open blades. Mr. Browning had observed the Rock Hill operations and felt that the technicians performed well. Mr. Browning's opinion, was that the white light boroscope inspection, a technique developed by the non-destructive testing (NDT) group at Hamilton Standard, was adequate to detect corrosion in the taperbore of the dimensions provided by the investigation team.

Several propeller designs have had problems. Although this propeller has more problems than Mr. Browning would prefer, he believed that this propeller was no worse than other designs.

8.2 FRANK WALSH

Mr. Walsh completed his Bachelor of Science degree in Mechanical Engineering, with some training at the Massachusetts Institute of Technology, Boston, Massachusetts. He has 30 years of government service, including working with the U.S. Navy. With the U.S. Navy, Mr Walsh was a vibration and sound engineer in a shipyard supervising 24 engineers. Later, Mr. Walsh worked at General Electric Aircraft Engines (GEAE) on the Navy Programs (NAVPRO) project heading the F404 second service program for Navy Air (NAVAIR). During NAVPRO, Mr Walsh was a program manager supervising twelve engineers. While at GEAE, he also established the group that reviewed all plans submitted to Pratt and Whitney (PW) for the manufacture of the first PW404 engines.

Mr. Walsh was hired by the Federal Administration (FAA) nine years ago as a propulsion engineer at the Engine and Propeller Directorate, Burlington, Massachusetts. He was responsible for propulsion systems and propellers for numerous manufacturers, including Hamilton Standard, Sikorsky, and Dowdy. Before the FAA employment, Mr. Walsh had no aircraft propeller experience. Mr. Walsh had attended helicopter and fixed wing schools, but did not hold any licenses. At this time, he does not manage anyone else. After 30 years of government service, including experience with the U.S. Navy, pressure was part of the job.

The FAA, Engine and Propeller Directorate, has five inspectors. One inspector is for structures, one for propulsion, and so forth, within the certification program. Also, the office can could draw on other FAA area offices for support. The office also approves the Designated Engineering Representatives (DER) for the respective aircraft and appliance manufacturers. Experienced candidates are nominated for DER by their respective company based on length of service, previous projects, and their resume. The DERs serve as an extension of the FAA; however, all DER decisions are reviewed by the FAA. They are familiar with the FARs, collect required information, and submit the data. Additionally, the DER reports all failures of critical components immediately to the FAA.

The DER nominations for Hamilton Standard come to Mr. Walsh. When Mr. Walsh came to the FAA there were only two DERs at Hamilton Standard, all other DER appointments were approved by him. He had nine DERs at Hamilton Standard, and more coming. Mr. Walsh did not believe in the DER system before joining the FAA, because his experience in the Navy was to do all the work. Although it took awhile to get used to the FAA procedure, Mr. Walsh said the DER system was very workable. He has never rejected a DER candidate from Hamilton Standard, although he had rejected candidates from other companies. Mr. Walsh said that he could not do his job without DER support.

Mr. Walsh approved Mr. Browning's nomination as one of the DERs for Hamilton Standard. Mr. Walsh said Mr. Browning came from propeller design and later customer support as a DER. Me. Walsh said Mr. Browning was one of the first persons sent to aircraft accident investigation school. Mr. Walsh described Mr. Browning as very conscientious and very honest.

Mr. Walsh began managing all the certification activity for Hamilton Standard activities when he was hired nine years ago. Mr. Walsh described Hamilton Standard as good company, easier to deal with than others. He said Hamilton Standard follows the rules, submits all the required information. There are no problems or disagreements with Hamilton Standard, they are as good as they can get. Other companies have to be pushed.

Mr. Walsh oversaw the development of the Rock Hill repair procedures. Mr. Walsh had never visited the Rock Hill facility. Mr. Walsh felt that there was much experience at the Rock Hill facility since some of the key people came from headquarters.

Mr. Walsh said the 14RF propeller was very good compared to others, although there were overspeed problems early on. Mr. Walsh believed that the structural strength of the spar was adequate as certified, and that the failures were due to the action of an outside agent. The 14RF propellers were certified in 1984 to 1985 and the 14SF propellers were developed in 1986 to 1987. Mr. Walsh said that when EMB 120 sales took off, the workload at Hamilton Standard and the FAA also increased. Mr. Walsh indicated that he monitored the propeller service difficulty reports to zero in on repetitive problems. During the RF propeller overspeed problems of 1987 and 1988, there were with nine incidents. The FAA conducted investigations and formed special committees. Mr. Walsh became very familiar with the aircraft, and as a result, Hamilton Standard was about 65% to 75% of his workload and with the recent accident, Hamilton Standard is still a large part of his workload.

The FAA and Hamilton Standard conducted an intense investigation following the ATR accident. Mr. Walsh spent four days on site during the ATR investigation. He was perplexed by the taperbore failures because the design was valid. There had never been a problem with the cork, the taperbore, or the lead wool before. He wanted to get to the bottom of the problem. When the blade was opened up, it revealed gouges. He let the experts solve the problem while he oversaw the work.

The FAA decided that the DER was not allowed to go beyond design limits. Several years previously, the FAA and the Hamilton Standard defined the critical parts that needed FAA oversight. The definition of critical parts became a grey area and because of the accident, the taperbore was now considered critical. There was no written definition of a critical part or what was acceptable to the Administrator. Often, Hamilton Standard would call the FAA and request an FAA review.

Three weeks later there was a second accident in Brazil. Mr. Walsh did not travel to Brazil, but everything was brought to the United States. There was evidence that a crack grew from corrosion inside the taperbore therefore an inspection procedure needed to be developed, which resulted in the ultrasonic method. There was pressure on the company to define a plan, and put it in a Service Bulletin for FAA review.

The company established the ultrasound sheer wave inspection procedure for cracks, which Mr. Walsh evaluated. During the evaluation of the procedure it seemed like the answer to a maintenance prayer. The limitation of the procedure was it was based on two data points, the two blade failures. The FAA did its own analysis and evaluation and based on the propagation analysis Mr. Walsh believed that there were two inspection opportunities to catch the problem. Also, the FAA felt comfortable with the 1,250 cycle inspection interval for unpeened blades. Although there was little data the FAA was expecting further AD action. The FAA initially wanted a 30 day inspection period but felt that a 45 days was more realistic with a 15,000 blade population.

We were all relieved that following the 45 days inspection period, there was only about a 3% rejection rate. Examination of the returned blades, it became clear there was mechanical damage inside the taperbore. The repair action to repair the mechanical damage began with the development of PS960. A spar failure was considered a catastrophic failure, therefore, Mr. Browning was the DER for this repair, Mr. Walsh was the final reviewing authority for the PS960 repair.

The PS960 repair was intended to remove tool marks. The idea of a terminating action was chosen over repetitive inspection intervals because blending the mechanical damage was considered an adequate repair and the basis for the terminating action.

Mr. Walsh was sure he made comments on PS960 but could not recall specific issues. He would typically make comments in the margins of reports or focus on topics during verbal presentations. He might also seek assistance from an expert in the FAA.

He said he had seen corrosion in the taper fore from the ATR accident, although he was not good with a boroscope. Mr Walsh said he could see corrosion pits through the boroscope, but could not see well enough to evaluate the effectiveness of the boroscope inspection and relied on the engineers. Mr Walsh wore glasses.

Mr. Walsh indicated his days were very full from a workload standpoint. The current accidents were 100% of his workload, and as such they became the No. 1 priority. His day started with early calls from Europe, and ended with late calls from Alaska with weekend calls as well. He had also been involved in the investigation of previous accidents, including the EMB-120 accident at Eagle Lake, Texas, two accidents in Canada, EMB-120 overspeed issues, including overspeed committee work, and the Sikorsky S-58B aging aircraft issue.

[redacted]

Jerome D. Frechette
Powerplant Group Chairman

JDF 12/21/95