Log 2358

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 14, 1992

In reply refer to: A-92-25 through -28

Honorable Barry L. Harris
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

On April 5, 1991, Atlantic Southeast Airlines, Inc., flight 2311,[1] an Embraer EMB-120, N270AS, crashed during a landing approach to runway 07 at the Glynco Jetport, Brunswick, Georgia. The flight was a scheduled commuter flight from Atlanta to Brunswick, Georgia, operating under the provisions of Title 14 Code of Federal Regulations (CFR) Part 135, and was being conducted under instrument flight rules. The airplane was operating in visual meteorological conditions at the time of the accident. The airplane was destroyed; and the two pilots, the flight attendant, and all 20 passengers received fatal injuries.

The National Transportation Safety Board determined that the probable cause of this accident was the loss of control in flight as a result of a malfunction of the left engine propeller control unit (PCU) which allowed the propeller blade angles to go below the flight idle position. Contributing to the accident was the deficient design of the PCU by Hamilton Standard and the approval of the design by the Federal Aviation Administration (FAA). The design did not correctly evaluate the failure mode that occurred during this flight, which resulted in an

---

[1]For more detailed information, read Aviation Accident Report--"Atlantic Southeast Airlines, Inc., Flight 2311, Uncontrolled Collision with Terrain, an Embraer EMB-120, N270AS, Brunswick, Georgia, April 5, 1991" (NTSB/AAR-92/03)

uncommanded and uncorrectable movement of the blades of the airplane's left propeller below the flight idle position.

The investigation found no evidence that pilot actions, weather, or the airplane's flight control systems either caused or contributed to the accident. Simulation tests of asymmetric flaps, runaway aileron, and runaway rudder malfunctions found that in every case and with different pilots at the controls, it was possible to control and successfully land the airplane. These simulation tests were consistent with the certification findings that such malfunctions would not cause uncontrollable flight characteristics.

The circumstances of this accident indicated that a severe asymmetric lift and thrust condition caused a left roll that led to loss of control of the airplane. The Safety Board's investigation examined all the possible events that could have caused the loss of control. The powerplant and propeller examinations indicated that the engines were operating normally but that a propeller system malfunction occurred, causing abnormally low propeller blade angles and a high drag condition and loss of lift on the left side of the airplane.

Examinations of the left propeller components indicated a propeller blade angle of about 3 degrees at impact while the left PCU ballscrew position was consistent with a commanded blade angle of 79.2 degrees. The discrepancy between the ballscrew position and the position of the pitchlock acme screw is a strong indication that a disconnect between these two components occurred prior to impact and that the left propeller had achieved an uncommanded low blade angle below the normal flight range.

On the right engine, the pitchlock acme screw was in a position that corresponded to a propeller blade angle of 22.6 degrees, and the ballscrew was in a position of 24.5 degrees. This difference of 1.9 degrees is within the expected accuracy of the measurements. Therefore, the evidence indicates that the PCU on the right engine was properly controlling the right propeller blade angle prior to impact.

The discrepancy in the PCU was found to have been extreme wear on the PCU quill spline teeth that normally engaged the titanium-nitrided splines of the propeller transfer tube. It was found that the titanium-nitrided surface was much harder and rougher than the nitrided surface of the quill. Therefore, the transfer

tube splines acted like a file and caused abnormal wear of the gear teeth on the quill. The investigation found that wear of the quill was not considered during the certification of the propeller system.

Using measurements and the inspection procedures for the quill and transfer tube that are in the Hamilton Standard Alert Service Bulletin, it was determined that the left PCU quill spline was worn to the extent that its gear teeth did not engage the transfer tube spline. In addition, the test cell and flight tests showed that the propeller blade angle could not be controlled by the PCU with a disengaged transfer tube. In the test cell, the blade angle moved toward high pitch; however, the propeller was operating at zero airspeed and did not experience normal flight loads. In contrast, the flight tests showed that the blade angle would move toward low pitch with a disengaged transfer tube. The blade characteristics indicate that centrifugal and aerodynamic twisting moments tend to move the blades toward low pitch.

The Safety Board believes that the worn quill on the left engine PCU became disengaged from the transfer tube prior to the loss of control of the airplane during the approach to Brunswick. Moreover, the propeller blades moved to a low angle, resulting in an asymmetric lift and drag condition that exceeded the capability of the pilots to counteract with the airplane controls available.

The FAA certification office responsible for the propeller system reported that there had never been a reported problem with the spline tube-quill gear connection when it was equipped with the nitrided spline tubes. The nitrided surface was originally specified for the propeller system and had been manufactured until June 1990. A review of the FAA service difficulty reports and the malfunction or defect reports did not reveal any service problems with the original nitrided spline tubes.

The FAA and the manufacturer reported that the surface finish on the transfer tube spline was changed in order to improve the ability to manufacture the transfer tube. The manufacturer's various technical review committees, following the procedures of the FAA-approved Quality Program Manual and Engineering Systems Manual, concurred with the change to the titanium-nitrided coating. The manufacturer's past experience had indicated that the wear rate for the titanium-nitrided coating was three to four times less than the original nitrided finish.

However, wear was not considered a factor because the design load of the spline to quill is relatively small, about 7 inch-pounds.

Prior to approving the titanium-nitrided transfer tube for service, service engine test cell runs were accomplished from June 18 to August 1, 1987, using a General Electric turbine engine. During these tests, a total of 229.18 engine hours was accumulated, exceeding the 150 hours normally required for a propulsion system certification test. During the tests, the propeller was feathered twice every 55 minutes, resulting in an accumulation of 500 feather cycles. Additionally, the test cycle provided for 750 propeller reverse cycles and 750 cycles from ground idle to takeoff and back to ground idle. Both the transfer tube and the ballscrew quill were examined after the tests and found in good condition with no visible signs of wear.

The failure mode and effects analysis of all the propeller components were completed by the manufacturer, and a report was submitted to the FAA during the original certification of the propeller system. The components were grouped into two failure categories. The first group included failures that had a predicted probability of occurrence of less than 10^{-9}, and the second group included failures with a predicted probability of greater than 10^{-9}. The transfer tube and quill interface were listed in the first group and were assigned as an "on condition" inspection item because of the perceived extremely remote possibility of failure and the lightly loaded application. For an "on condition" component, inspection is only required after a problem is found during service. Since the transfer tube and quill were considered structural parts having a remote possibility of failing, verification of the propeller system response following the failure of these components was not required.

The certification standards for reversible propellers are contained in 14 CFR section 35.21. These standards state, in part, the following:

> A reversible propeller must be adaptable for use with a reversing system in an airplane so that no single failure or malfunction in that system during normal or emergency operation will result in unwanted travel of the propeller blades to a position substantially below the normal flight

low-pitch stop. Failure of structural elements need not be considered if the occurrence of such a failure is expected to be extremely remote[2].

During the investigation, the Safety Board became aware of incidents involving another problem with the PCU. On three occasions involving different airplanes, the operators found that a propeller would not feather during ground tests. The PCUs were sent to the manufacturer's facility for overhaul. Unlike the worn quill problem, the inspection of the PCU components found that the ballscrew teeth that engage the quill were extremely worn and would not engage the gear teeth on the quill. As in the case of the worn quills, the manufacturer believed that the disengagement would only occur during the relatively high torque loads during a feather/unfeather check and that servo ballscrew wear was not a safety of flight issue.

The most recent occurrence of servo ballscrew wear was on February 28, 1992, when an Air Littoral EMB-120 experienced a loss of propeller control after takeoff from Rome, Italy. After takeoff, the pilot noticed that the engine was overtorquing to about 110 percent and that propeller speed was dropping. He reduced the power lever angle to flight idle and returned to the airport. The subsequent landing and rollout were uneventful. The inspection of the PCU revealed extreme wear on the outer diameter splines of the servo ballscrew to the extent that the servo ballscrew would not fully engage the quill.

The investigation found that wear of the quill was not considered during the certification of the propeller system because of the very light torque loading on the quill during flight. Service history of the PCU quill prior to the introduction of the titanium-nitrided transfer tube indicated that quill spline wear was not a problem. Additionally, the manufacturer provided an analysis during certification indicating that even in the event of a failure, the propeller would either drift into the feathered position or maintain the blade angle present when the failure occurred. However, the accident involving flight 2311 and the subsequent investigation have determined that these assumptions, although originally supported by numerous engineering evaluations and manufacturing experience, are invalid and that there are single failure modes that could result in uncommanded propeller blade angles below flight idle.

---

[2]The FAA has defined "extremely remote" as being a possibility of failure of less than 10^{-9}.

The Safety Board notes that there have been four reported instances of extreme wear of the PCU servo ballscrew, one of which was discovered in flight. The worn parts were not in contact with a titanium-nitrided surface or a surface that had a finish rougher than allowed in the specifications. Therefore, the wear of the servo ballscrew is another case where wearing of the components was not considered in the certification. The Safety Board believes that if the engagement between the ballscrew and the quill fails, it would be possible for the propeller blade angle to rotate below the flight idle angle, resulting in loss of control of the airplane. The Safety Board concludes that the Hamilton Standard model 14RF propeller system does not comply with the purpose of the certification requirements contained in 14 CFR section 35. Therefore, the FAA should conduct a certification review of the Hamilton Standard propeller model 14RF and all propeller systems that are based upon a similar design philosophy.

The Safety Board notes that prior to the emergency airworthiness directive issued in May 1991, inspection of the PCU transfer tube or ballscrew quill was to be conducted "on condition." Thus, the part was only to be inspected if a problem was noted. The accident involving flight 2311 and a recent finding of extreme wear of the servo ballscrew quill indicate that "on condition" maintenance of a PCU, or waiting for it to fail in service prior to inspection, could result in the loss of the airplane. Therefore, the FAA should establish a periodic inspection requirement for Hamilton Standard propeller model 14RF PCUs and other similar propeller systems.

The investigation found that the flightcrew spent the night before the accident on a layover in a hotel and that the flightcrew had been scheduled to be off duty for about 8 hours. This scheduled "reduced rest" period provided the crew with about 6 to 6.5 hours of rest from the time that they checked into their hotel until they received their wakeup calls. The rest time of the airline's flightcrews, including the pilots of flight 2311, complied with the reduced rest provisions of 14 CFR Part 135. The FAA, upon publishing the flight time limitations and rest requirements for Part 135 scheduled operations in 1985, referred to the use of the reduced rest provisions of the regulation and stated:

> The purpose of the rest reduction is to allow scheduling flexibility for the benefit of air carriers, pilots, and the flying public. Although this rule allows for scheduling a reduced rest, it does not allow for any reduction of the minimum reduced rest or the minimum compensatory rest under any circumstances. Therefore, in order to benefit fully from

> this flexibility, an air carrier should schedule realistically to avoid any possible flight schedule disruptions. The FAA expects that most air carriers will schedule at least 9- to 11-hour required rest periods. But in those instances when air carriers need to schedule a shorter rest or when rest must be reduced because actual flight time has exceeded scheduled flight time, the rule allows for some scheduling flexibility.

The FAA further stated that:

> The FAA wants to stress that the goal of these revisions is to prevent fatigue....It is the responsibility of both the operator and the flight crewmember to prevent fatigue, not only by following the regulations but also by acting intelligently and conscientiously while serving the traveling public. This means taking into consideration weather conditions, air traffic, the health of each flight crewmember, or any other circumstances (personal problems, etc.) that might affect the flight crewmember's alertness or judgment on a particular flight.

During the rulemaking process, airline and airline association representatives assured the FAA that the reduced rest provisions of the proposed regulation, necessary to provide an air carrier with the flexibility to cope with operational delays, would be applied by air carriers on a contingency basis and that they would not be used to routinely develop daily schedules.

The reduced rest provisions of the regulation allow an air carrier to shorten the rest period of a flightcrew to accommodate operational delays when they are encountered. However, a review of the duty and rest time of the accident flightcrew and other pilots of the airline indicated that reduced rest periods were scheduled for about 60 percent of the layovers in day-to-day operations. A review of other commuter airlines indicated a similar tendency to schedule duty cycles that would require reduced rest schedules.

The FAA has recently commissioned a working group to study the flightcrew duty time for operations conducted under 14 CFR Part 135. The working group is expected to convene officially after May 1992, and it will be part of the Aviation Rulemaking Advisory Committee.

Although the circumstances of this accident established that flightcrew fatigue was not a factor, the Safety Board is concerned that Atlantic Southeast Airlines, Inc., not unlike other commuter air carriers, scheduled reduced rest periods for about 60 percent of the layovers in its day-to-day operations. The Safety Board believes that this practice is inconsistent with the level of safety intended by the regulations, which is to allow reduced rest periods as a contingency to a schedule disruption, and that it has the potential for adversely affecting pilot fitness and performance.

Therefore, the Safety Board believes that the FAA should reiterate and clarify to the Regional Airline Association and commuter air carriers the intent of the reduced rest provisions of 14 CFR 135.265 and require air carriers to apply the regulation in a manner consistent with that intent.

As a result of its investigation of this accident, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Conduct a certification review of the Hamilton Standard model 14RF propeller system and require appropriate modification to ensure that the propeller system complies with the provisions of 14 CFR Section 35.21. The certification review should include subjecting the system to the vibration spectrum that would be encountered in flight on those aircraft for which it is certificated. (Class II, Priority Action) (A-92-25)

Examine the certification basis of other model propeller systems that have the same design characteristics as the Hamilton Standard propeller model 14RF and ensure that the fail-safe features of those propeller systems will function properly in the event of unforeseen wear of components in the propeller system. (Class II, Priority Action) (A-92-26)

Establish a periodic inspection time requirement for the transfer tube splines, servo ballscrew and ballscrew quill on Hamilton Standard model 14RF propellers and other propeller systems of similar design. (Class II, Priority Action) (A-92-27)

Issue an Air Carrier Operations Bulletin (ACOB) directing Principal Operations Inspectors to clarify with their operators that the intent of 14

CFR Section 135.265 is not to routinely schedule reduced rest, but to allow for unexpected operational delays, and to require compliance with the intent of the regulation. (Class II, Priority Action)(A-92-28)

Also, as a result of the investigation, the Safety Board issued Safety Recommendation A-92-29 to Atlantic Southeast Airlines, Inc., and A-92-30 to the Regional Airline Association.

Acting Chairman COUGHLIN, and Members LAUBER, HART, HAMMERSCHMIDT, and KOLSTAD concurred in these recommendations.

By: Susan M. Coughlin
Acting Chairman