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U.S. Accident Report: Failure of Propeller Control System Downs Aircraft

A sudden, violent roll sent an Embraer EMB-120 plunging to the ground while on landing approach. A U.S. National Transportation Safety Board report determined that a failure in the left-engine propeller control unit caused an unrecoverable loss-of-control.

Editorial Staff Report

The twin-turboprop commuter aircraft with 20 passengers on board was turning left on final approach at 1451 hours local time, when it rolled violently to the left. It crashed into trees seconds later less than two miles from the runway, in a steep nose-down attitude with its wings almost perpendicular to the ground.

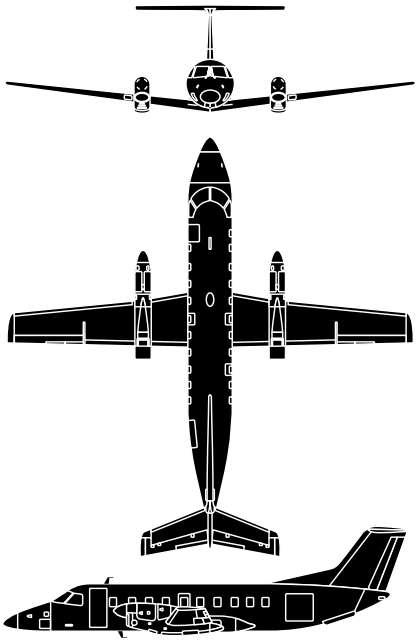
The aircraft, an Embraer EMB-120 being operated under U.S. Federal Aviation Regulation (FAR) Part 135, was destroyed. The Embraer's two pilots and a flight attendant were also killed. The scheduled Atlantic Southeast Airlines flight crashed 9,975 feet (2,992 meters) short of runway 07 at Glynco Jetport near Brunswick, Georgia. The aircraft was being operated in visual meteorological conditions at the time of the April 5, 1991, accident.

A U.S. National Transportation Safety Board (NTSB) report released late last year concluded that a propeller system failure caused the aircraft to become uncontrollable. The report said the pilots of Flight 2311 "could not have prevented the accident."

The NTSB determined that the probable cause of the accident was loss of flight control resulting from a malfunction of the left-engine propeller control unit (PCU) that allowed propeller blade angles to go below the flight idle position.

"Examinations of the left propeller components indicated a propeller blade angle of about three degrees at impact while the left propeller control unit ballscrew

position was consistent with a commanded blade angle of 79.2 degrees," the NTSB said. "The discrepancy between the actual propeller blade angle and the angle commanded [by the] screw is a strong indication that there was a discrepancy inside the propeller control unit prior to impact and that the left propeller had achieved an uncommanded low blade angle."



The Embraer EMB-120 Brasilia was first flown in 1983. The twin turboprop passenger aircraft can seat up to 30 passengers. It has a long-range cruising speed at 25,000 feet of 260 knots (482 kilometers) an hour. It has a range of 945 nautical miles (1,750 kilometers) at 25,000 feet with a maximum 30-passenger payload. The aircraft has a service ceiling of 29,800 feet.

Source: *Jane's All the World's Aircraft*

The NTSB added: "The discrepancy in the propeller control unit 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 report also noted that the "investigation found that wear of the quill was not considered during the certification of the propeller system.

"Contributing to the accident was the deficient design of the propeller control unit by Hamilton Standard [the manufacturer] and the approval of the design by the [U.S.] Federal Aviation Administration," the NTSB said. "The design did not correctly evaluate the failure mode that occurred during this flight, which resulted in an uncommanded and uncorrectable movement of the blades of the airplane's left propeller below the flight idle position."

Flight 2311 was en route from Atlanta, Georgia, to Brunswick, Georgia. The flight crew was finishing a duty sequence that began the day before with a round trip from Atlanta to Tallahassee, Florida. They returned to Atlanta on the morning of the accident and flew a round trip to Montgomery, Alabama, before preparing for the accident flight.

The flight crew was originally assigned to fly another aircraft to Brunswick, but mechanical problems required an equipment change to the accident aircraft. "No problems were noted by the flight crews on the previous flights [4 flights on the same day]," the NTSB said, referring to the accident aircraft.

The captain, 34, held an airline transport pilot certificate with ratings for the EMB-120, EMB-110 and the de Havilland Canada DHC-7. He also held an airframe and powerplant mechanic certificate. At the time of the accident, he had logged more than 11,700 flight hours, of which 5,720 were in the EMB-120.

The captain had been "actively involved in the acceptance of the first EMB-120 placed in service in the United States and received his training from the manufacturer at the same time as the FAA project pilot, who subsequently gave him his type rating flight check," the NTSB report said.

"The inspector commented on the flight check form, 'Excellent flight check and oral test, has extensive knowledge of aircraft and systems. Excellent pilot techniques,'" the NTSB said.

The first officer, 36, held an airline transport pilot certificate with ratings for multi-engine land and commercial single-engine land privileges. He had logged 3,925 flight hours, of which 2,795 were in the EMB-120.

The accident aircraft was manufactured in 1990. It was equipped with two Pratt & Whitney of Canada PW-118 engines and Hamilton Standard 14RF-9 propellers. The airplane had accumulated about 816 hours of total flight time and 845 cycles. "There were no recurring pilot complaints or maintenance discrepancy cards concerning the flight control systems, engines, propellers or auto-pilot system," the NTSB report said.

The investigation determined that the aircraft was within its allowable weight and center-of-gravity limitations during the flight.

Weather conditions at the time of the accident were reported as scattered clouds at 2,500 feet, estimated 10,000 feet broken, ceiling 20,000 feet broken, wind 160 degrees at 10 knots and visibility seven miles.

The accident aircraft was not equipped (and was not required to be equipped) with either a cockpit voice recorder (CVR) or a flight data recorder (FDR). CVRs are now required on multi-engine turbine-powered airplanes with six or more passenger seats. FDRs are now required on commuter airplanes with 20 or more passenger seats.

The impact site was flat terrain in a densely forested area. The total length of the wreckage path was about 250 feet from where the airplane first struck the tops of the trees.

"Damage to the trees indicated that the airplane was banked nearly 90 degrees to the left and in a steep angle of descent at impact," the NTSB said. "All of the airplane's structure was accounted for at the wreckage site. There was no evidence of any in-flight fire or pre-impact separation of airframe components."

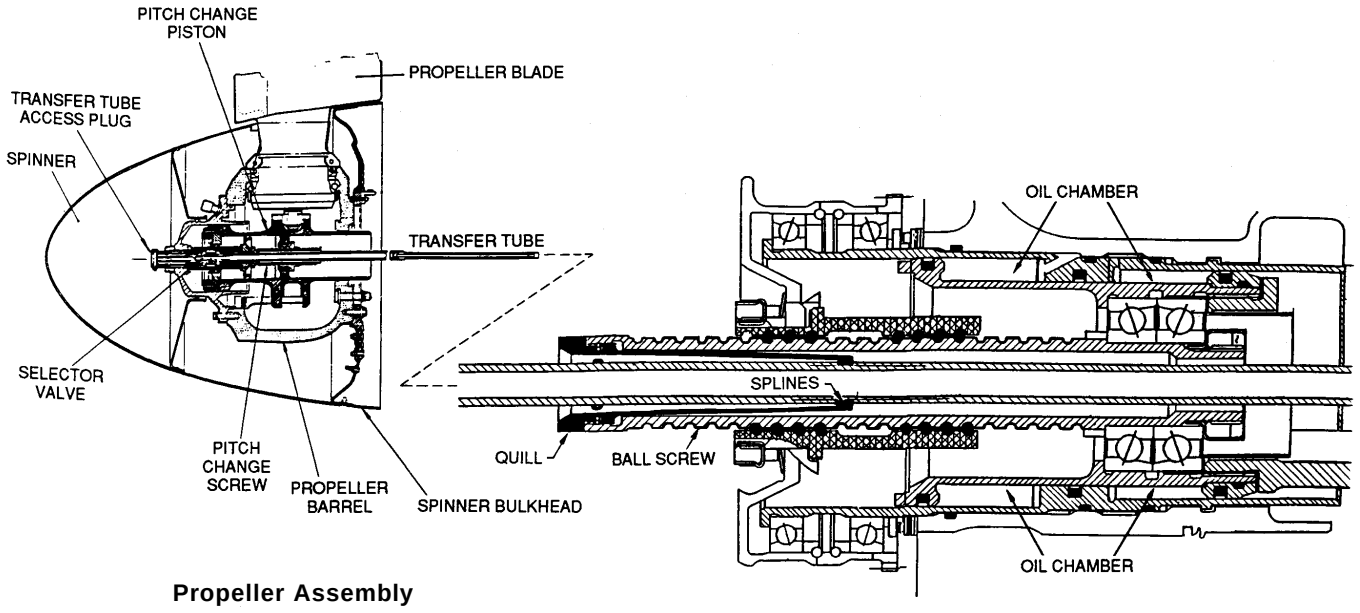
According to the NTSB, teardown inspections of both engines revealed no evidence of pre-impact damage or malfunction. In addition, the report said there was no evidence of damage that could be associated with either engine having an overspeed condition.

[The PW-118 is a turbo-propeller engine consisting of two modules, the turbo-machinery module and the reduction gearbox module, joined to form a single unit. The reduction gearbox drives a flange-mounted propeller shaft and also provides accessory drives.

The Hamilton Standard 14RF-9 propeller is a flange-mounted, controllable-pitch, dual-acting, full-feathering, reversible, four-blade propeller with composite blades. The propeller and PCU are mounted on a common centerline and connected through the propeller shaft by the oil transfer tube. The transfer tube provides high-pressure oil from the gearbox-mounted main oil pump to the propeller hub. The PCU governor provides metered oil pressure to operate a ballscrew drive that imparts rotary motion to the transfer tube by means of a splined quill. The transfer tube turns an acme screw in the pitch assembly. The acme screw positions the pitch change selector valve, which directs oil to the '"increase pitch" or "decrease pitch" side of the piston.] (Figure 1)

"The PCU ballscrew position was measured on both units," the NTSB said. "The measurements indicated that the PCU ballscrew position for the left propeller was in a location that would coincide with a PCU-commanded propeller blade angle of 79.2 degrees, which is the feathered position. The PCU ballscrew position for the right propeller corresponded to a commanded propeller blade angle of 24.5 degrees."

Hamilton Standard Propeller System Model 14RF



Source: *U.S. National Transportation Safety Board*

Figure 1

According to the NTSB, ballscrew quills from both PCUs had severely worn internal splines. (Figure 2, page 5)

"The spline teeth on the left quill were almost entirely worn away, and the wear pattern was slightly off the axial centerline. The right quill spline wear was more eccentric with a heavy wear pattern on one side and relatively little wear on the opposite teeth."

The NTSB noted: "During the inspection of the PCU quills, Hamilton Standard representatives and engineers stated that while the extreme wearing of the quill was unusual, the FAA certification tests and computer simulation modeling of the propeller system indicated that the disengagement of the quill from the transfer tube would not result in an unsafe condition. The representatives stated that such a disengagement would result in the propeller either staying at the blade angle in which the disengagement occurred or eventually assuming the feathered or streamlined position."

According to the NTSB report, a PCU for the model 14RF-9 was returned to Hamilton Standard for repair in January 1991. "During the service inspection, it was found that the splines on the quill were extremely worn."

The report said the unit had about 3,931 hours of service. Three other worn PCU quills were discovered by Hamilton Standard overhaul personnel in the following four months, the NTSB said.

"All of the PCUs that contained these quills were sent in for service after the operators found that the propeller would not feather or unfeather during a ground test. The manufacturer's engineers stated that these PCUs were originally equipped with a transfer tube that had the titanium-nitrided (harder and rougher) splines."

Based on the number of worn quills found (including those in the accident aircraft), the manufacturer issued an alert service bulletin "that advised all operators to inspect PCUs for worn quills and began a fleet campaign to remove from service the titanium-nitrided transfer tubes and to replace them with the original nitrided tubes." The alert detailed recommended inspection intervals and quill wear limits.

A month later, the FAA issued an emergency airworthiness directive (AD), based on the service bulletin, that required inspection at a maximum of 500 hours of service of the PCU ballscrew quill installations that had titanium-nitride transfer tubes.

However, reports that followed the initial inspections indicated that allowable wear limits needed to be reduced and periodic inspection intervals shortened.

The FAA issued another emergency AD two weeks later reducing the initial time-in-service inspection to a maximum of 200 hours and reducing wear limits and repetitive inspection hours for quills returned to service.

"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 NTSB said. It said that Hamilton Standard's technical review committees, following procedures outlined in the FAA-approved *Quality Program Manual and Engineering Systems Manual*, agreed with the change to titanium-nitrided coating.

The first titanium-nitrided transfer tubes entered service in July 1990 after being reviewed and approved by FAA certification engineers.

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During the accident investigation, the NTSB said that it became aware of "incidents involving another problem with the Hamilton Standard PCU used on the EMB-120."

The NTSB added: "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 ... 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 problem was first noted in September 1990 and again in March 1991 and May 1991.]

In February 1992, an EMB-120 experienced loss of propeller control (the engine was overtorquing to 110 percent and propeller speed was dropping) after takeoff from Rome, Italy — an incident that was later linked to servo ballscrew wear, the NTSB said. "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 pilot successfully returned the aircraft to the airport after he was able to shut down the engine and feather the propeller.

Hamilton Standard has since issued a service bulletin providing for periodic inspections for wear of the internal splines on the 14RF-9 propeller. On April 10, 1992, the FAA issued an AD requiring compliance with the Hamilton Standard bulletin.

In the Brunswick accident, the NTSB concluded that after the worn quill on the left engine PCU became disengaged from the transfer tube, an asymmetric lift and drag condition was created that "exceeded the capability of the pilots to counteract with the airplane controls available."

The NTSB said that there was apparently sufficient engagement between the quill and the transfer tube during the preflight feather/unfeather check to permit a successful check, but that the quill "continued to wear on the transfer tube until complete disengagement of the splines occurred."

Under these circumstances, recovery was impossible, the NTSB said. "Simulation tests found that as the propeller blade angle was reduced below the 22-degree stop setting used in the flight tests, the airplane became increasingly difficult to control. Indeed, as the blade angle approached about 3 degrees, the airplane was uncontrollable. After numerous attempts, with the left propeller assuming low blade angles, the test pilot could only crash in a wings-level attitude by reducing the power on both engines to flight idle. At very low blade angles, the rolling moment became too large to be counteracted by the flight controls."

As a result of its investigation, the NTSB said there is evidence that the Hamilton Standard model 14RF propeller "does not comply with the purpose of the certification requirements of [U.S. Federal Aviation Regulations] 14 CFR Section 35.21."

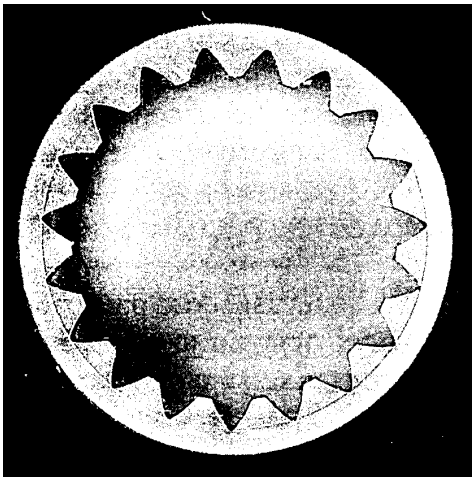
The NTSB also noted that:

- Mechanical wear of the transfer tube, quill, or servo ballscrew was not considered a factor during the certification process because of the relatively low torque loading on these components and the manufacturer's analysis indicating that the propeller blade angle would go to the feathered position if a failure occurred.

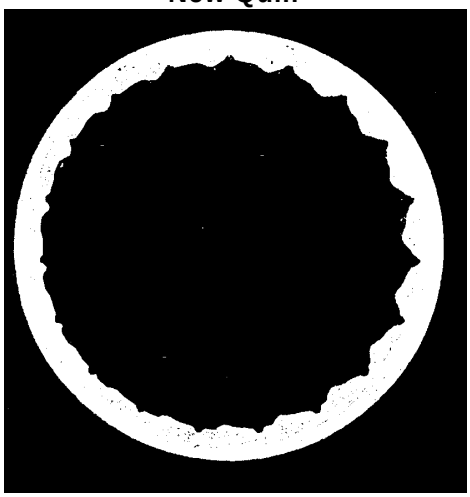
- Contrary to the FAA's fail-safe design requirements, the propeller system did not feather as predicted by the manufacturer's analysis and propeller simulation model.

- Certification testing of the titanium-nitrided transfer tube, accomplished in a test cell using a different engine than that certificated for the EMB-120, did

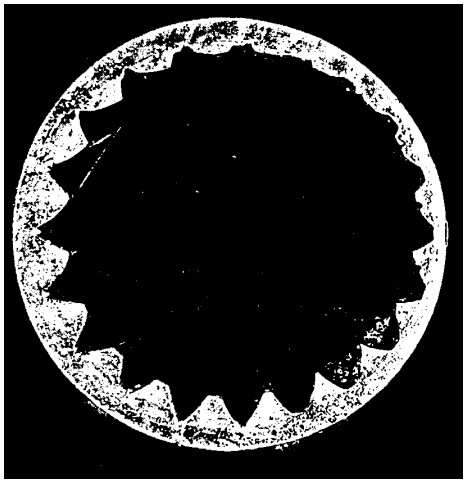
New Propeller Control Unit Quill Compared with Quills from Accident Aircraft



New Quill



Left Engine Quill



Right Engine Quill

Source: ***U.S. National Transportation Safety Board***

Figure 2

not simulate the in-flight loads and vibration environment of actual service. [Hamilton Standard's engineering analysis and testing of the titanium-nitrided transfer tube indicated that the use of this coating would not compromise the safety of the propeller system.]

- The transfer tube, quill and servo ballscrew were certificated without a requirement for periodic inspection.

Based on its investigation of the Brunswick accident, the NTSB recommended that the FAA conduct a certification review of the Hamilton Standard model 14RF propeller system and require modification to ensure that the propeller system complies with federal guidelines. "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."

The NTSB also called for examination of the certification basis of other propeller systems that have the same design characteristics as the 14RF, to "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." ♦

ACCIDENT PREVENTION
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