



Missing Screws Send Commuter Plummeting

U.S. National Transportation Safety Board officials say failure to follow required maintenance procedures and poor management supervision led to the violent inflight breakup of Continental Express Flight 2574.

by
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When accident analysts trace the chain of events that have led to a specific aviation accident, the links are usually more dramatic and sophisticated than missing screws.

But in the case of the structural inflight breakup of Continental Express Flight 2574, an Embraer 120 twin turbo-prop, 47 missing screws were determined to be the cause of the tragedy. Three crew members and 11 passengers were killed in the crash.

The U.S. National Transportation Safety Board (NTSB) cited the failure of Continental Express maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures. It said the lapses led to the sudden inflight loss of the partially secured left horizontal stabilizer leading edge and the immediate, severe nose-down pitch and breakup of the airplane.

Failure of the Continental Express management to ensure compliance with approved maintenance procedures and the failure of U.S. Federal Aviation Administration (FAA) surveillance to detect and verify such compliance were cited as contributing causes by the NTSB, which released its report late last year.

Flight Events Traced

At 0909, local time, on Sept. 11, 1991, Continental Express Flight 2574 departed Laredo International Airport, Laredo, Texas, en route to Houston. The flight was initially assigned flight level FL250 (25,000 feet) and later was instructed to descend to FL240 (24,000 feet).

After receiving a radar handoff, the flight crew made initial radio contact with the Houston Air Route Traffic

Control Center (ARTCC) for the Eagle Lake sector at approximately 0948:43. At 0959:51, Houston ARTCC gave the flight instructions to “fly heading zero three zero, join the Humble two three four radial GLAND, rest of route unchanged.” The flight crew acknowledged the instructions. It was the last radio transmission from the flight.

Just before losing communications with the flight, two Houston ARTCC controllers for the sector were relieved by another controller. During the position relief briefing, all three controllers noticed the loss of the airplane’s radar beacon return for the flight. At 1004:53, the radar controller who had assumed duty made four unsuccessful attempts to contact the flight. The controller then advised his supervisor that radar and radio contact had been lost.

The cockpit voice recorder (CVR) revealed normal conversation during the descent from FL240. Following the last radio transmission, the CVR recorded the flight crew receiving automated terminal information service (ATIS) at about 1000:03. At 1003:07, the cockpit area microphone (CAM), as recorded on the CVR, picked up sounds of objects being upset in the cockpit. These sounds were followed immediately by one that resembled a “human grunt.”

The remaining sounds were produced by the airplane’s aural warning systems, as well as mechanical sounds indicating the breakup of an aircraft in flight. The sound of wind was recorded by the CAM beginning at 1003:13. The CVR tape stopped at 1003:40, about 33 seconds after the onset of the sound of objects being upset in the cockpit.

Radar data and a readout of the airplane’s flight data recorder (FDR) indicate the airplane was descending through 11,800 feet mean sea level (MSL) when a sudden pitchdown occurred. FDR data showed that there was then a sudden negative vertical acceleration of at least 3 1/2 negative g-force, as well as roll and yaw moments, heading changes and sudden changes in engine parameters.

Before pitching down, the aircraft engines were operating normally. At the start of the pitchdown, FDR data revealed an abrupt oscillation in propeller speed, recorded in percentage of standard revolutions per minute (rpm). Propeller rpm initially decreased from what had been a constant 85 percent for both engines. Within two seconds, however, the rpm for both engines increased. No. 2 engine decreased again but then increased to well over 100 percent until the data ended.

After impact with the ground, the airplane came to rest upright, in a wings level attitude, the burning wreckage embedded partially in the ground. There were no survivors. The bodies of two occupants were outside the airplane. Both pilots were still strapped in their seats.

The accident occurred in daylight visual meteorological conditions (VMC).

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None of the 47 screws that would have attached the upper surface of the leading edge assembly for the left side of the horizontal stabilizer was found during NTSB’s examination of the wreckage. There was also no evidence of distress in the upper attachment holes for the left side leading edge assembly or any indication that the attaching screws were installed when the left side leading edge assembly separated from the horizontal stabilizer. In addition, a “lip” was formed on the forward-most frame on the left lower side. That frame (spar cap) was the area into which the screws mounted the underside of the left side leading edge assembly, and this area showed signs of distress.

The lower attachment screws had been installed, but the leading edge assembly had separated from the stabilizer. The spar cap on the lower left side of the horizontal stabilizer showed evidence of being pulled down, forcing it to project into the wind stream along with the leading edge. This pulling damage, the NTSB said, was consistent with the left side leading edge assembly having been ripped down and away from the lower attaching screws as it separated from the horizontal stabilizer.

Routine Maintenance Started Fatal Error Chain

The night before the accident, maintenance personnel from the airline’s second (evening) shift and from the third (midnight) shift worked on the airplane at the Houston hangar.

The second shift pulled the airplane into the hangar at 2130 hours for scheduled maintenance, which included removal and replacement of both the left and right horizontal stabilizer deice boots.

According to the NTSB, a change of either the left or right deice boot required that the leading edge/deice boot assembly for that side of the horizontal stabilizer be removed. Normally, the old deice boot would be stripped

from the composite structure of the leading edge, and, while still attached to the stabilizer, the deice fluid lines would be disconnected. The leading edge would then be removed and a new deice boot would be bonded to the structure. The leading edge/deice boot assembly would be reinstalled on the stabilizer with 47 attaching screws for the top and bottom sides of the assembly.

With the assistance of an inspector, two second-shift mechanics gained access to the T-tail, about 20 feet above the ground, by using a hydraulic lift work platform. The work was assigned by the second-shift supervisor who took charge of the aircraft. The two mechanics removed most of the screws on the bottom side of the right leading edge and partially removed the deice boots bonded to the front of the right side leading edge.

The inspector, who had climbed on top of the T-tail, removed the attaching screws on the top of the right side leading edge and then walked across the T-tail and removed the attaching screws from the top of the left side leading edge. (The second-shift inspector later told the NTSB that he placed the screws removed from the top row of the left and right sides of the horizontal stabilizer in a bag and left them on the manlift.) The screws that held the stabilizer leading edge assembly in place were not removed. The top sets of attaching screws for both the left and right horizontal stabilizer leading edge assemblies were not visible from the ground.

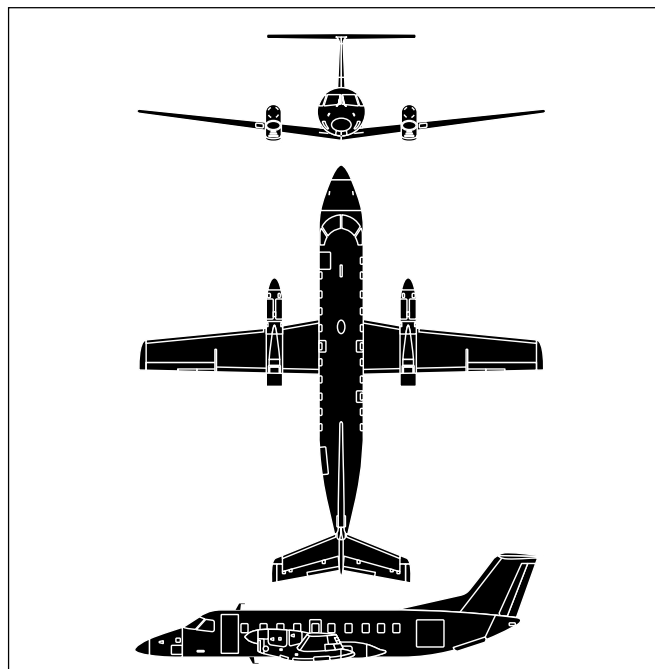
Following a shift change by third-shift mechanics, the right leading edge assembly was removed from the horizontal stabilizer. A new deice boot was bonded to the front of the leading edge at a workbench in the hangar. During the third shift, the Embraer 120 was pushed outside the hangar to make room for another airplane. With no direct light on the airplane, work on the stabilizer resumed and third-shift mechanics reinstalled the right side leading edge assembly, using new and used screws to attach the top and bottom of the assembly to the right horizontal stabilizer.

The second-shift work on the airplane was indicated on the shift inspector's written turnover sheet. However, the incoming third-shift inspector reviewed the sheet before the entry was made. The third-shift maintenance supervisor and mechanics were not verbally informed of the removal of the upper screws on the left side leading edge.

M-602 work order card(s) had originally been assigned to the third shift for completion. But the second-shift supervisor, who was assigned to the airplane, elected to start work on the deice boots to help ease the third shift's workload. In addition, the supervisor did not issue the M-602 work order cards to the second-shift mechanics because they were in a package assigned to the third shift. As a result, no entries were made on the reverse

sides of the M-602 work order cards that would have advised the third-shift supervisor and mechanics that work had been started by the second shift on *both* the left and right deice boots.

A third-shift inspector later reported that he had gained access to the top of the horizontal stabilizer to assist with the installation and inspection of deice lines on the right side of the stabilizer. He said that he was not aware of the removal of the screws from the top of the left leading edge assembly. He said that in the darkness outside the hangar, he did not see that the screws were missing.



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*

Based on interviews and statements, the NTSB traced the following significant maintenance events the night before the accident:

2000: The second-shift supervisor and another supervisor (normally assigned to the flight line but who was assigned to work on the accident airplane) discussed bringing the airplane into the hangar.

2100: The supervisor who took charge of the airplane told a second-shift mechanic to remove both deice boots.

2130: The airplane was brought into the hangar by the second-shift supervisor. A second-shift inspector informed another second-shift supervisor, who was now

responsible for the airplane, that he would volunteer to assist with the boot changes.

2145: A third-shift flight line supervisor arrived and noted that the third-shift supervisor was already there.

2200: The second-shift supervisor responsible for the airplane observed two mechanics and the second-shift inspector kneeling on the right stabilizer and removing the right boot.

The third-shift hangar supervisor observed the second-shift inspector lying on the left stabilizer and observed two mechanics removing the right boot.

The third-shift supervisor, who was working in the hangar, asked the second-shift supervisor if work had started on the left stabilizer. The third-shift supervisor observed the supervisor look up at the tail of the airplane and state, "No."

The third-shift supervisor told the second-shift supervisor that he would be able to change the right deice boot that evening, but that the left deice boot change would be made on another night. He said he would return the left replacement boot to stock.

2205: The third-shift inspector arrived for work early and saw that the majority of the right deice boot had been removed. He reviewed the inspector's turnover form and found no writeup because *the second-shift inspector, who had removed the upper screws, had not yet made his log entries.* (Emphasis added.)

2230: The second-shift supervisor filled out the inspector's turnover form with the entry, "helped the mechanic remove the deice boots."

The second-shift mechanic who had been removing the deice boot gave a verbal turnover to the second-shift supervisor and was instructed to give his turnover to a third-shift mechanic. That third-shift mechanic was not assigned to the accident airplane. He later stated that he recalled seeing the bag of removed screws on the manlift. He gave a verbal turnover to another third-shift mechanic who later did not recall receiving a turnover and stated that he did not see the bagged screws.

Another third-shift mechanic arrived and was informed by the supervisor that he was assigned to the accident airplane's boot replacement and that he should talk to the second-shift supervisor to find out what had been accomplished. There was no discussion about which of the two second-shift supervisors the mechanic should consult; he

chose to speak with the second-shift supervisor in charge of a check on another airplane. He then asked what had been done during the second shift. The mechanic observed the supervisor point to the tail of the airplane and say that a few stripped screws had prevented the second-shift mechanics from removing the right leading edge.

The mechanic then asked if any work had been performed on the left deice boot. The supervisor informed him that he did not think there would be time to change the left deice boot that evening.

2245: The third-shift line supervisor left the hangar to work at the gate and had no involvement with the accident airplane.

2300: The second-shift supervisor responsible for the airplane left work. Before he went home, he had not talked to the other second-shift supervisor, the third-shift supervisor, who was working the hangar, or the third-shift supervisor in charge of line checks.

Subsequently, the airplane was cleared for flight. The first flight was at 0700, and there is no evidence from the morning preflight that the flight crew was aware of any

of the work performed on the horizontal stabilizer. Moreover, the NTSB said, U.S. Federal Aviation Regulations (FAR) and the airline's guidelines did not require them to be informed of such work.

The first flight from Houston to Laredo was without incident. The accident occurred during the return flight.

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Maintenance Factors Examined

The NTSB went into considerable detail tracking the sequence of events in the hangar and the actions of the various shift supervisors, inspectors and mechanics. It cited the following links in the accident chain, or "accident would not have occurred," factors:

- The second-shift supervisor responsible for the airplane failed to solicit an end-of-shift verbal report from the two mechanics assigned to remove the deice boots. Moreover, he failed to give a turnover to the oncoming third-shift supervisor and to complete the maintenance/inspection shift turnover form. He failed to give M-602 cards to the mechanics so that they could record the work that had been started but not completed by the end of their shift. The NTSB believed that the accident would most likely not have occurred if this supervisor had solicited a verbal shift turnover; had passed that information

on to the third-shift supervisor; had completed the maintenance shift turnover form; and had ensured that the mechanics who worked on the deice boots had filled out the M-602 cards so that the third-shift supervisor could have reviewed them.

- The other second-shift supervisor, who was not responsible for the airplane, assigned two mechanics to the supervisor responsible for the airplane. He received a verbal shift turnover from one of the mechanics, but this turnover came after he had already given a verbal shift turnover to the incoming third-shift supervisor, informing him that no work had been done on the left stabilizer. When he received the verbal turnover from the mechanic, he failed to fill out a maintenance shift turnover form and failed to inform the oncoming third-shift supervisor. In addition, he did not direct the mechanic to give his verbal shift turnover to the second-shift supervisor (who was responsible for the airplane) or to the oncoming third-shift supervisor. Instead, he instructed the mechanic to seek out a third-shift mechanic and to tell him what work had been done.

The NTSB said that because the second-shift supervisor (who was not responsible for the airplane) gave a verbal turnover to the incoming third-shift supervisor and because he accepted the verbal turnover from the second-shift mechanic, he had assumed responsibility for the airplane. More important, if the second-shift supervisor had instructed the mechanic to seek out the second-shift supervisor who was responsible for the airplane and who had actually assigned him the job, or to seek out the incoming third-shift supervisor with his verbal shift turnover information (and had instructed the mechanic to complete the M-602 cards), the accident most likely would not have occurred.

- The second-shift quality control inspector who assisted the two mechanics with the removal of the upper screws on both horizontal stabilizers signed the inspector's turnover sheet and went home. A third-shift quality control inspector arrived at work early, reviewed the turnover sheet and recalled no entry. Unfortunately, the incoming inspector reviewed the shift turnover sheet before the second-shift inspector wrote "helped mechanic pull boots" on it. In addition, the

second-shift inspector failed to give a verbal shift turnover to the oncoming third-shift inspector. The NTSB said that if the second-shift inspector had given a verbal shift turnover to the incoming inspector and had reported any work initiated regarding removal of the upper leading edge screws on both stabilizers, the accident most likely would not have occurred.

The NTSB noted that the second-shift inspector had reportedly demonstrated substandard performance in the past for which he had been disciplined. In August 1991, he was given a warning because he had "missed a crack ... inspection of engine exhaust stack." During that same month, he was given a second warning because he "did not finish all paperwork required [and] missed 15 task cards on the accountability sheet."

- One of the mechanics who had assumed responsibility for the work accomplished on the airplane during the second shift failed to give a verbal shift turnover to the second-shift supervisor responsible for the airplane and who had assigned him to remove the deice boots. Nor did he solicit and fill out the M-602 work cards from the second-shift supervisor before leaving at the end of his shift. The NTSB said that if the mechanic had given a verbal shift turnover to the second-shift supervisor or if he had given his turnover to the oncoming third-shift supervisor directly and solicited the M-602 work cards from the second-shift supervisor, the accident most likely would not have occurred.

The NTSB noted that the second-shift inspector had reportedly demonstrated substandard performance in the past for which he had been disciplined.

Status of Required Inspection Items Disputed

There was disagreement on whether the maintenance on the deice boot or deice boot/stabilizer leading edge assemblies fell under the FAR-mandated Required Inspection Items (RII) category or under a less critical standard maintenance item. Continental Express management (along with supervisory and maintenance personnel) contended that the leading edge/deice boot assembly was a calendar inspection item. They argued it was not integral to the structure of the horizontal stabilizer, and thus not within the requirements of RIIs as set forth in the FAR. Furthermore, they contended that if this "nonstructural" member was so critical to flight, including its loss resulting in inflight destruction of the airplane, it should have been identified as an RII item by the manufacturer under the requirements of the FAR RII.

Embraer, the airplane manufacturer, contended that the deice boot or deice boot/leading edge assembly was clearly part of the entire stabilizer assembly, thus falling within the requirements of the FAR and the specific definition of “stabilizer” as an RII.

The NTSB stated that the Continental Express maintenance and quality assurance personnel erred in not considering the removal and replacement of the horizontal stabilizer leading edge deice boot an RII. The NTSB said it was aware that a deice boot would not constitute an RII. But, because the leading edge of the stabilizer must be removed to replace the deice boot, the NTSB concluded that the process of changing the deice boot should have been designated an RII so that maintenance quality control would have been more rigorous.

The NTSB made the following recommendations to the FAA:

- In cooperation with aircraft manufacturers and airlines, conduct a review of the regulations, policies and practices related to establishing Required Inspection Items (RIIs) for airline maintenance departments with a view toward developing more specific identification of RIIs.
- Require that airlines study the feasibility of developing a means to advise flight crews about recent maintenance, both routine and nonroutine, on the airplanes that they are about to fly. This would enable the crews to be alert to discrepancies during preflight inspections and possibly to make an additional inspection of critical items, such as RIIs that may affect the safety of flight.

NTSB Member John K. Lauber, Ph.D., filed a strong dissenting statement:

I am perplexed by the majority [board] decision that the actions of Continental Express senior management were not causal in this accident. The report identifies “substandard practices and procedures and oversights” by numerous individuals, each of whom could have prevented the accident. Included are mechanics, quality assurance inspectors and supervisors, all of whom demonstrated “a general lack of compliance” with approved procedures. Departures from approved procedures included failures to solicit and give proper shift-change turnover reports, failures to use maintenance work cards as approved, failures to complete required maintenance/inspection shift turnover forms, and a breach in the integrity of the quality control function by virtue of an inspector serving as a mechanic’s assistant during the early stages of the repair work performed on the accident aircraft.

Another factor to be considered here was the failure of Continental Express maintenance and quality assurance personnel to treat the deicing boot replacement, which requires removal of the leading edge of the horizontal stabilizer, as a Required Inspection Item. By doing so, a separate inspection by quality control inspectors would have been required of the work performed that night. Even though regulations clearly establish that the horizontal stabilizer is an RII, Continental Express maintains that the deicer boot/leading edge assembly was a “nonstructural” item and, therefore, not subject to the more rigorous inspection requirements. I find it very disturbing that senior personnel responsible for aircraft maintenance apparently do not understand that the leading edge of any airfoil is a critical determinant of the aerodynamic characteristics of that airfoil, and thus that improper repair work would seriously compromise the safety of an aircraft.

Still another factor that I believe to be highly relevant here was the absence of a lead mechanic and a lead inspector as specified in the ground maintenance manual. Senior management’s failure to fill these positions in effect diffused and diluted the chain of authority and accountability among maintenance and inspection personnel at Continental Express. A detailed examination of the organization aspects of the maintenance activities the night before the accident reveals a melange of crossed lines of supervision, communications and control. This situation, more than any other single factor, was directly causal to this accident.

The multitude of lapses and failures committed by many employees of Continental Express discovered in this investigation is not consistent with the notion that the accident resulted from isolated, as opposed to systemic, factors. It is clear, based on this record alone, that the series of failures which led directly to the accident were not the result of an aberration, but rather resulted from the normal, accepted way of doing business at Continental Express. The conclusions in our report note the “failure of management to ensure compliance with air carrier policy” and its failure to “establish an effective safety orientation for its employees.” Line management of an airline has the regulatory responsibility for not only providing an adequate maintenance plan but for implementing the provisions of that plan as well. By permitting, whether implicitly or explicitly, such deviations to occur on a continuing basis, senior management created a work environment in which a string of failures, such as occurred the night

before the accident, became probable. Accordingly, their role must be considered causal in this accident.

Finally, I note for the record my concerns about the way certain factual background information regarding senior management personnel has been handled in this report. As discussed in our Board meeting, but not in the report, two senior managers at Continental Express previously held positions of key responsibility at two other airlines, one airline of which was the subject of both civil and criminal litigation for maintenance-related practices, and the other airline which experienced a major accident which this Board determined to be, in part, due to failures and deficiencies in that airline's maintenance program and in the management thereof. Both people were in line management positions within their maintenance organizations during the time of the deficient practices, all of which involved deviation of actual practices from those specified in relevant, official and approved documents. I am in no better position than anyone else to determine how *directly* relevant to the present accident this information is. However, since it is factual information of the kind we routinely collect in any accident investigation, and is already in the public record, and since it is clearly not inconsistent with the management practices noted in this investigation, I believe it is relevant to the discussion, and thus deserves explicit mention here. To do otherwise is to make a *de facto* decision that this information is clearly *not* relevant, a decision which I am unwilling to support.

The NTSB noted at least four circumstances where, if proper action had been taken, this accident would not have occurred. Shift changes and the indifference to passing on orally or in writing what work had been done by the personnel involved clearly show how and why the 47 missing screws went undetected. Although the airline apparently had standard operating procedures (SOPs) to guide supervisors, inspectors and mechanics through the

steps taken in making the repairs, those SOPs were apparently treated as more of a nuisance than a necessity.

SOPs are vital to the cockpit environment because they provide a system of monitored checks and cross-checks to ensure that every phase of aircraft operation is accomplished routinely with safety of flight paramount.

SOPs for maintenance personnel are no less vital to the safety of flight. This accident demonstrates that point. If the SOP calls for a verbal briefing, do it. If the SOP calls for filling out a work order form, do it and do it so that other maintenance personnel involved with repairing the airplane will know exactly what was done and how.

Safety is everybody's business, and it is the responsibility of management to promote it. If management condones indifference, shortcuts, casual compliance to SOPs, and, as Lauber says, fails to "establish an effective safety orientation for its employees," the entire operation becomes a breeding ground for accidents.

The tragedy of the 47 missing screws demonstrates that aviation safety is a team effort. The number of maintenance personnel involved in replacing the deice boots on this airplane gives ample testimony to this fact. Some aviation functions may seem more glamorous, but it is a team that gets the airplane in the air and back on the ground safely. ♦

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