09/11/91 Britt Airways, Inc., d/b/a Continental Express

Official Accident Report Index Page

Report Title

BRITT AIRWAYS, INC., d/b/a CONTINENTAL EXPRESS FLIGHT 2574 IN-FLIGHT STRUCTURAL BREAKUP EMB-120RT, N33701 EAGLE LAKE, TEXAS SEPTEMBER 11, 1991

Facts of the Accident

Accident NTSB ID	92-04
Airline	Britt Airways, Inc., d/b/a Continental Express
Model aircraft	EMB-120, 120-L77
Aircraft manufacturer	Embraer
Engine manuafacturer	Pratt & Whitney
Date	09/11/91
Time	1003
Location	Eagle Lake, Texas
Country	USA
IFR or VFR?	VFR
Fatalities	14
Injuries	-
Fire during flight?	Y
Fire on the ground?	Y
Probable cause	The failure of Continental Express maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures for the airplane's horizontal stabilizer deice boots that led to the sudden in-flight loss of the partially secured left horizontal stabilizer leading edge and the immediate severe nose-sown pitchover and breakup of the airplane.
Contributing causes	The failure of the continental Express management to ensure compliance with the approved maintenance procedures, and the failure of FAA surveillance to detect and verify compliance with approved procedures.
Weather conditions	Visibility 6 miles, haze
Total crew size	3
Cockpit crew size	2
Cabin crew size	1
Passengers	11
Report ID	NTSB/AAR-92/04
Pages	87
Day or night?	Day
Flight number	2574
Flight origin	Laredo International Airport, TX
Flight destination	Houston Intercontinental Airport
Description	The aircraft experienced a structural breakup in flight and crashed in a cornfield near Eagle Lake, Texas. The horizontal stabilizer, or top of the T-type tail, had

separated from the fuselage before ground impact. Examination revealed that the 47 screw fasteners that would have attached the upper surface of the leading edge assembly for the left side of the horizontal stabilizer were missing. They had been removed the night before during scheduled maintenance.

Abstract:

This report explains the structural breakup in flight and crash of Continental Express Flight 2574, an Embraer 120, in a cornfield near Eagle Lake, Texas. The safety issues discussed in this report include the feasibility of developing a means to advise flightcrews of recent maintenance work on aircraft and the need for reviewing regulations, policies and practices for establishing required inspection items (RIIs) with a view toward developing more specific identification of RIIs. Safety recommendations concerning these issues were made to the Federal Aviation Administration.

Executive Summary

On September 11, 1991, about 1003 Central Daylight Time, Continental Express Flight 2574, an Embraer 120, operating under Title 14 of the Code of Federal Regulations, Part 135, experienced a structural breakup in flight and crashed in a cornfield near Eagle Lake, Texas. The 2 flight crewmembers, 1 cabin crewmember and 11 passengers aboard the airplane were fatally injured.

The National Transportation Safety Board determines that the probable cause of this accident was the failure of Continental Express maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures for the airplane's horizontal stabilizer deice boots that led to the sudden in-flight loss of the partially secured left horizontal stabilizer leading edge and the immediate severe nose-down pitchover and breakup of the airplane. Contributing to the cause of the accident was the failure of the Continental Express management to ensure compliance with the approved maintenance procedures, and the failure of FAA surveillance to detect and verify compliance with approved procedures.

The issues in this investigation focused on:

1. The responsibilities of the Federal Aviation Administration and aircraft manufacturers and operators to determine the critical items and inspection levels of aircraft systems.

2. The procedures for relaying and standardizing maintenance shift turnover information.

As a result of this investigation, the Safety Board issued safety recommendations to the Federal Aviation Administration on the feasibility of developing a means to advise flightcrews of recent maintenance work on aircraft and the need for reviewing regulations, policies and practices for establishing required inspection items with a view toward developing more specific identification of such items. Also, as a result of this investigation, on February 28, 1992, the Safety Board issued safety recommendations to the Federal Aviation Administration that would enhance both flight standards surveillance of Continental Express and flight standards Program Guidelines, including the National Aviation Safety Inspection Program.

1. Factual Information

1.1 History of the Flight

On September 11, 1991, about 1003, Central Daylight Time (CDT), Continental Express Flight 2574, an Embraer 120, operating under Title 14 of the Code of Federal Regulations, Part 135 (14 CFR 135), experienced a structural breakup in flight and crashed in a cornfield near Eagle Lake, Texas.1

The flight, with call sign "Jetlink 2574," departed Laredo International Airport, Texas (LRD), about 0909, en route to Houston Intercontinental Airport (IAH). Following takeoff, the flight was assigned a cruise altitude of flight level 250 (FL250). The flightcrew was later instructed to descend to FL240.

After receiving a radar handoff, the flightcrew made initial radio contact with Houston Air Route Traffic Control Center (Houston ARTCC) radar controllers for the Eagle Lake sector at approximately 0948:43. At 0954:14, Houston ARTCC instructed the flight to "...cross five five miles southwest of Intercontinental [IAH] at and maintain niner thousand." At 0954:20, the flightcrew responded, "OK fifty-five miles southwest of Intercontinental at niner thousand, we're out of flight level two four zero...."

At 0959:51, Houston ARTCC instructed the flight, "Jetlink twenty-five seventy-four, roger, fly heading zero three zero, join the Humble two three four radial GLAND, rest of route unchanged." The flightcrew responded at 0959:57, "Zero three zero, join the GLAND six arrival, twenty-five seventy-four." The response was the last radio transmission from the flight.

Just prior to losing radio communications with the flight, the two Houston ARTCC controllers for the Eagle Lake Sector were relieved by another controller. During the position relief briefing, all three controllers noticed the loss of the airplane radar beacon return for Jetlink 2574. At 1004:53, the radar controller, who had assumed duty, initiated the first of four attempts to contact the flight. The flightcrew did not respond. The radar controller then advised his supervisor that radio and radar contact had been lost.

The cockpit voice recorder (CVR) revealed normal conversation during the descent from FL240. Appendix E contains the CVR transcript. Following the last radio transmission, at 0959:57, the CVR recorded the flightcrew receiving automated terminal information service (ATIS) "Golf" on radio No. 2, 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 was comparable to a human "grunt."

The remaining sounds were warnings produced by the airplane's aural warning systems, as well as mechanical sounds indicating breakup of an aircraft in flight. The sound of wind was picked up 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. The entire CVR recording lasted for 31 minutes and 6 seconds.

Radar data and a readout of the airplane's flight data recorder (FDR) showed the airplane in descent, passing through about 11,800 feet mean sea level (msl), when a sudden pitchover occurred. The FDR data showed that there was then a sudden negative vertical acceleration of at least 3 1/2 negative g, as well as roll and yaw moments, heading changes, and sudden changes in engine parameters.2

Prior to the pitching over of the airplane, the engines were operating normally. At the start of the sudden pitchover, FDR data revealed a sudden 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. However, within 2 seconds, the rpm for both engines increased. No. 2 engine rpm decreased again, but then increased to well over 100 percent until the data ended.

All the eyewitnesses who were interviewed observed the occurrence from the ground. A total of eight witnesses reported that they saw the airplane for at least part of the time after they realized it was in distress, until impact.

The following describes various eyewitness observations of the airplane:

- flying normally
- wings level, slightly nose down3
- suddenly consumed by fireball
- wingtips and part of tail protruding from fireball
- a bright flash
- orange or red-orange flames at time of flash or immediately thereafter

- sputtering engines, followed by three pops
- a revving sound
- a flat spin to the left until impact
- left wing dangling from blown out area
- right wing missing
- flying parts during downward spiral

After impact, the airplane was upright, in a wings-level attitude, partially imbedded in the ground and burning.

Local fire and rescue personnel responded to the crash and extinguished the fire. All persons aboard the airplane were fatally injured, and the bodies of two of the occupants were lying outside of the airplane. Both pilots were still strapped in their seats.

The accident occurred in visual meteorological conditions (VMC), in daylight. The main wreckage, including the cockpit and cabin, came to rest at 29°30'98" north latitude and 96°23'21" west longitude.

1.2 Injuries to Persons

	Flightcrew	Cabincrew	Passengers	Other	Total
Fatal	2	1	11	0	14
Serious	0	0	0	0	0
Minor	0	0	0	0	0
None	0	0	0	--	0
Total	2	1	11	0	14

1.3 Damage to Aircraft

The airplane was destroyed in the crash and fire. The airplane was valued at around $7.75 million.

1.4 Other Damage

There was no claim for damage to the harvested cornfield and pasture land into which the main wreckage and other portions of the airplane fell.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 29, was born on April 20, 1962. He was hired by Continental Express Airlines on October 10, 1987. He held airline transport pilot certificate No. 565336474, with ratings for the EMB-120 and Airplane Multiengine Land. His most recent Federal Aviation Administration (FAA) first-class medical certificate was issued on July 18, 1991, with the limitation: "Holder shall wear correcting lenses while exercising the privileges of his airman certificate." Company records indicate that at the time of the accident the captain had accumulated approximately 4,243 total flying hours, of which 2,468 were in the EMB-120.

The captain received his initial ground school and proficiency check in the EMB-120 as a first officer, completing the training on October 29, 1988. He completed upgrade ground school training on September 21, 1989, and received a type rating in the EMB-120 on September 29, 1989. He completed his initial operating experience and received a line check on October 2, 1989. His last proficiency check was on March 9, 1991. His last recurrent training was completed on May 29, 1991, and his last line check was accomplished on August 8, 1991.

1.5.2 The First Officer

The first officer, age 43, was born on November 9, 1947. He was hired by Continental Express Airlines on March 12, 1990. He held airline transport pilot certificate No. 1963386, with ratings for the EMB-120 and Airplane Multiengine Land. His most recent FAA first-class medical certificate was issued on August 30, 1991, with no limitations. Company records indicate that, at the time of the accident, the first officer had accumulated approximately 11,543 total flying hours, of which 10,300 were obtained prior to his employment with Continental Express. He had a total of 1,066 hours in the EMB-120.

The first officer completed initial ground school in the EMB-120 on March 30, 1990. He completed flight training on April 19, 1990. His initial operating experience and line check were completed on April 24, 1990. He was subsequently upgraded to captain on the EMB-120, completing that training and initial operating experience on May 14, 1990. Although he no longer held a regular captain's bid number, the airline allowed the first officer to retain his currency as a captain. He received proficiency checks on October 29, 1990, and April 11, 1991.

1.5.3 Management and Maintenance Personnel

The president, age 51, was hired in July 1990, as President of the Commuter Division of Continental Airlines, Inc. Continental Express is a wholly owned subsidiary of Continental Airlines. He had worked previously for Eastern Airlines (owned by the same parent company as Continental and Continental Express), from January 1987 to July 1990, in several successive positions: Staff Vice President and Counsel for Regulatory Compliance; Vice President for Base Maintenance; Special Assignment; and Vice President for Administration. Prior to his employment with Eastern Airlines, he had worked for New York Air (1980-1986) and had served as its Vice President for Operations. He holds a commercial pilot certificate with ratings and limitations of airplane single engine land with instrument privileges. He also holds a private pilot certificate with ratings and limitations of airplane multiengine land.

The Senior Director of Maintenance and Engineering, age 48, was hired in August 1990. He had worked previously for Eastern Airlines, from September 1989 to August 1990, as Manager of Special Projects. From June 1987 to June 1989, he worked for Aloha Airlines, first as Director of Quality Control and then as Director of Maintenance. His Airframe and Powerplant License was issued on April 10, 1968.

The Senior Director of Quality Assurance and Control, age 46, was hired in February 1991. He had worked for Eastern Airlines from 1969 to 1991 and had served as Manager of Aircraft Inspection. His Airframe and Powerplant certificate was issued on June 26, 1979.

The second shift supervisor, age 28, who was in charge of N33701, was hired by Continental Express on April 9, 1988, as a mechanic. He was promoted to shift supervisor on January 19, 1990. His previous employment included service with the U. S. Army from 1982 to 1985. His Airframe and Powerplant certificate, number 383749034, was issued on December 19, 1987.

The second shift inspector, age 25, who removed the attaching screws from the tops of the left and right horizontal stabilizer leading edge assemblies, was hired on July 11, 1989, as a mechanic. He was promoted to inspector on October 24, 1990. His previous employment included service as an aircraft electrician in the U. S. Navy. His Airframe and Powerplant certificate, number 456456725, was issued on February 5, 1989. The inspector had received company discipline on two occasions that related to inspections. In August 1991, he received a warning for having "missed a crack...in inspection of engine exhaust stack." He received a second warning that month because he "did not finish all paperwork required...missed 15 task cards on the accountability sheet."

The company had a written policy for disciplinary action that included the following forms of progressive discipline: verbal counseling or reprimand; formal counseling and written warning; probation; suspension; dismissals; and immediate dismissal without notice. According to the written policy, "there is no precise formula for applying discipline" so no specific action would be taken after a specific number of warnings.

The second shift mechanic, age 43, was hired on July 2, 1990, as a mechanic. His previous employment included work as an aircraft mechanic with Continental Air Micronesia (1989-1990), and flight line mechanic and inspection dock chief with the U. S. Air Force (1986-1989). He holds Airframe and Powerplant certificate number 451760789 issued on March 7, 1990.

The second shift supervisor, age 29, (who was not responsible for N33701), was hired on October 25, 1987, as a mechanic. He was promoted to inspector in 1989 and to shift supervisor on January 19, 1990. He was previously employed as an airplane mechanic for two fixed-based operators (1987) while he completed school. His Airframe and Powerplant certificate, number 451396613, was issued on January 26, 1988.

The third shift supervisor, age 26, was hired by Britt Airways, Inc., (later merged into Continental Express), on June 8, 1987, as a mechanic at the air carrier's Cleveland base. He was promoted to an inspector on November 27, 1989, transferred to the Houston base as a mechanic on March 16, 1990, and was promoted to shift supervisor on August 17, 1990. His previous employment included work as a helicopter mechanic and crew chief in the U. S. Army (1984-86), and as a jet engine mechanic in the U. S. Air Force Reserves (1986-87). His Airframe and Powerplant certificate, number 312767386, was issued on June 16, 1989.

The third shift inspector, age 36, was hired by Britt Airways, Inc., (later merged into Continental Express), as a maintenance helper at the Bloomington, Indiana, base on September 1, 1982. He was promoted to aircraft mechanic in 1986. In 1989, he spent 9 months at the Houston base where he was promoted to inspector. He returned to the Houston base as an inspector on May 1, 1991. His Airframe and Powerplant certificate, number 347508432, was issued on April 26, 1986.

The hangar workers, consisting of mechanics, inspectors, and supervisors, who were directly involved in work on the tail structure of the airplane, represented about 23 percent of the second shift workers and 21 percent of the third shift workers employed by Continental Express at the time of the accident. Together, they represented about 15 percent of the entire hangar workforce from all shifts.

1.6 Aircraft Information

1.6.1 The Airplane

The airplane, U.S. registration N33701, was an Embraer EMB-120, manufactured in Brazil. The serial number was 120-L77. Continental Express Airlines acquired the airplane on April 15, 1988. Records showed that the airplane had accumulated 7,229.8 hours and 10,009 cycles as of September 10, 1991. The airplane was configured with 10 rows of double passenger seats on the right side of the cabin and 10 rows of single passenger seats on the left side of the cabin.

The gross takeoff weight for the airplane, upon departure from LRD on the accident flight, was calculated by the flightcrew as 22,272 pounds, including 1,815 pounds for passengers, 259 pounds for cargo, and 3,100 pounds for takeoff fuel. The calculated weight for the takeoff from LRD was 3,081 pounds below the maximum allowable takeoff weight of 25,353 pounds.

The airline's EMB-120 Aircraft Operations Manual stated,

> *The balance of the aircraft is controlled by the load in the aft cargo hold. To keep aircraft CG [center of gravity] within allowable limits, there are minimum and maximum loads for the aft cargo hold which vary as the passenger load varies.*

A table provided in the airline's Alert Bulletin 91-17, dated September 3, 1991, established a minimum weight of 78 pounds and a maximum weight of 794 pounds for a passenger load of 11 persons. The documented load of 259 pounds in the aft cargo hold was within CG limits.

1.6.2 Maintenance Information

The procedures for maintaining the airplane were contained in the airline's General Maintenance Manual (GMM), which was approved by the FAA (See section 1.17.2). A review of the maintenance records for N33701 was conducted, and personnel responsible for the maintenance and inspection of N33701 the night before the accident were interviewed (See section 1.17.1).

1.7 Meteorological Information

There were no significant meteorological information (SIGMET) advisories or center weather advisories (CWAs) in effect for the area before or after the time of the accident.

The weather conditions reported by the National Weather Service for Palacios, Texas, which was the nearest reporting station to the accident site, were:

0950 (about 15 minutes prior to the accident):

Estimated ceiling 3,000 feet broken, 10,000 feet broken, 25,000 feet overcast, visibility 6 miles, haze, temperature 83 degrees, dewpoint 74, wind 070 degrees at 7 knots, altimeter 30.08.

At 1050, about 45 minutes after the accident, the reported weather at Palacios, Texas, was:

Estimated ceiling 3,000 feet broken, 10,000 feet broken, 25,000 feet broken, visibility 7 miles, haze, temperature 86 degrees, dewpoint 74, wind 070 degrees at 7 knots, altimeter 30.03.

1.8 Aids to Navigation

At 0959:51, Houston ARTCC directed the airplane to

> *...fly heading zero three zero, join the Humble two three four radial GLAND, rest of route unchanged.*

This radio transmission was the last one that the flight acknowledged.

At the time of the accident, the airplane was in a descent under positive radar control by Houston ARTCC, Eagle Lake Sector, and had been instructed to intercept the radial. There were no difficulties regarding aids to navigation or air traffic control (ATC) reported in this accident.

1.9 Communications

Houston ARTCC's communications with the flight took place for approximately 11 minutes, beginning at 0948:43, when the flight reported in, "Houston Center Jetlink twenty-five seventy-four flight level two four zero." The last transmission from the flight occurred at 0959:57, with Jetlink 2754 acknowledging Houston ARTCC's instructions to "...join the GLAND six arrival...." (See appendix E).

Neither the CVR nor ATC tapes indicate any communication difficulties between the crewmembers nor between the flight and air traffic controllers until after communications in the airplane and from the airplane were lost. From the beginning of the CVR recording, at 0933:36, until the sound of objects moving in the cockpit, at 1003:07, there is no difficulty indicated in any of the communications or background sounds. The first officer, however, remarked at 0936:29, "Do you smell something like paint thinner?" and the captain replied, "A little bit, yeah."

The first indication that there might have been some difficulty was the lack of response to three calls from the Houston ARTCC Eagle Lake Sector controller to "Jetlink twenty-five seventy-four, say altitude," at 1004:53, 1005:12, and 1005:32. All three controllers for the Eagle Lake Sector (two outgoing and one incoming) noted about the time of the change to the relief controller that the radar return for Jetlink 2574 had disappeared from the screen.

1.10 Aerodrome Information

The flight was inbound to IAH. The airport elevation is 98 feet msl. The airport is operated continuously. There are four primary nonintersecting runways, the longest of which, 14L/32R, is 12,000 feet long by 150 feet wide.

There were no difficulties reported regarding any aerodrome in this accident.

1.11 Flight Recorders

The CVR and FDR were recovered from their installed positions in the aft portion of the airframe. There was minor damage to the recorder cases from impact forces. The recorders showed no evidence of having been subjected to fire. The CVR recording was clear and showed no evidence of loss in quality as a result of crash damage. The FDR recording was also of good quality.

1.12 Wreckage and Impact Information

Separated parts of the airplane, including all eight propeller blades, were within about a 1.5 nautical mile radius of the main wreckage.

The horizontal stabilizer, or top of the T-type tail, had separated from the airplane before impact and was lying about 650 feet west-southwest of the main wreckage. Some of the structure and skin from approximately the upper third of the vertical stabilizer were still attached to the horizontal stabilizer. The lower two thirds of the vertical stabilizer remained attached to the tail cone in the main wreckage. The leading edge/deice boot assembly for the left side was missing from the horizontal stabilizer. The left side leading edge/deice boot was later found by investigators in a small corral about 3/4 mile west of the main impact site.

The left engine and propeller assembly, minus the four propeller blades, was lying approximately 370 feet **south**-southeast of the main wreckage. The left wing was in the wreckage, still attached to the fuselage by the lower attachment points, but it was folded under the fuselage and the inboard portion of the right wing. The right wing was in its proper position, still attached to the main fuselage. Part of the right wing tip was found about 1/5 mile west of the main impact site. The right engine remained attached to the right wing, and the four propeller blades were separated from the propeller hub assembly.

Both engines and propeller systems, including the eight separated propeller blades, were sent to the facilities of the engine manufacturer for disassembly and inspection, under the supervision of the Safety Board. The disassembly and inspection determined that the right engine had oversped and overtorqued before impact. The left engine had no evidence of overspeed or overtorque. The eight propeller blades that had separated from their attaching points to the hubs, and the hub side attaching points, were fractured. There was no evidence of a defect or anomaly in either engine or propeller assembly prior to the unusual attitudes and in-flight breakup of the airplane. The damage to the engines and propellers was compatible with the results of extreme changes in airplane attitudes, and, in the case of the left engine, separation from the airplane before ground impact.

The Colorado River, flowing approximately north to **south**, ran about 1.2 miles west of the main crash site. An agricultural pilot, who flew over the crash site shortly after impact, reported seeing a piece of airplane wreckage floating down the river. However, investigators did not find any wreckage in the river.

During the Safety Board's examination of the wreckage, 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. There was no evidence of distress in the upper attachment holes for the left side leading edge assembly or 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 forwardmost frame on the left lower side of the horizontal stabilizer spar cap. That frame (spar cap), with receptor holes for the lower attaching screws, was the area into which the screws mounted the underside of the left side leading edge assembly to the stabilizer. This lower frame area showed signs of distress. Figure 1a, figure 1b, figure 1c, figure 1d show the condition of the left horizontal stabilizer leading edge.

The lower attachment screws remained installed, but the leading edge assembly had separated from the stabilizer, with the exception of a small portion of composite structure remaining below the two farthest inboard screw heads. The spar cap on the lower left side of the horizontal stabilizer showed evidence of being pulled down so that it would project into the wind stream along with the leading edge. This pulling damage is 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. This evidence was consistent with screws missing on the top side of the left leading edge assembly, and the lower attaching screws holding fast, pulling down the frame (spar cap) on the lower side of the stabilizer, and thereby forming the lip.

The main portion of the airplane came to rest upright and partially imbedded in the cornfield on a heading of about 360 degrees. There was no indication that the main wreckage moved after initial ground impact.

The crash site was approximately 3 miles **south**-southwest of the town of Eagle Lake, Texas, and 60 nautical miles west-southwest of IAH.

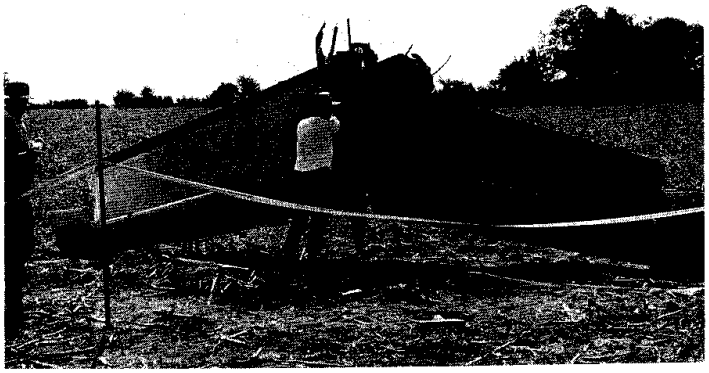

Figure 1a.--View of horizontal stabilizer from underside.

Figure 1b.--Leading edge assembly and outboard portion
of left side of horizontal stabilizer.

Figure 1a.--View of horizontal stabilizer from underside.

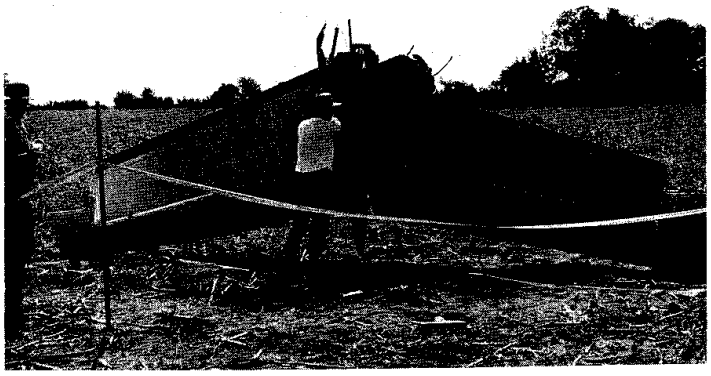

Figure 1a.--View of horizontal stabilizer from underside.

Figure 1b.--Leading edge assembly and outboard portion
of left side of horizontal stabilizer.

Figure 1b.--Leading edge assembly and outboard portion of left side of horizontal stabilizer.

Figure 1c.--Front frame of left side of horizontal stabilizer
with lower screw attaching area angled downward.

Figure 1d.--View of interior leading edge assembly for left side
of horizontal stabilizer.
Note that upper screw attachment holes (lower) show no signs of distress.

Figure 1c.--Front frame of left side of horizontal stabilizer with lower screw attaching area angled downward.

Figure 1c.--Front frame of left side of horizontal stabilizer
with lower screw attaching area angled downward.

Figure 1d.--View of interior leading edge assembly for left side
of horizontal stabilizer.
Note that upper screw attachment holes (lower) show no signs of distress.

Figure 1d.--View of interior leading edge assembly for left side of horizontal stabilizer.

Note that upper screw attachment holes (lower) show no signs of distress.

The nose section and the bottom surface of the forward section of the fuselage were crushed. The extreme aft section of the fuselage, including the still attached upper 2/3 of the vertical stabilizer, had compression impact damage.

The fuselage cargo door that was found 18 feet from the main wreckage had deep grooves and scratches in the outer skin. Instantaneous overloading was apparent on the bayonet fittings and roller attachments at the forward and aft cargo door frames. The lower half of the cabin boarding door remained attached to the fuselage; and the door operating handle was in the stowed position. The main landing gears and the nose gear were in their stowed positions. The nose landing gear was displaced upward by impact forces.

1.13 Medical and Pathological Information

1.13.1 Flightcrew and Passengers

Autopsies performed on the 3 crewmembers and 11 passengers by the Harris County Coroner's Office, Texas, determined that all occupants sustained fatal traumatic injuries consistent with sudden impact. Two occupants were ejected from the aircraft at impact. Most persons who were found inside the airplane were subjected to the postimpact fire. No evidence of preimpact fire injuries or smoke inhalation by occupants was found.

Toxicological analyses were completed on specimens of the captain's blood and urine and on other tissues of the first officer and flight attendant because samples of their blood and urine were not available. The captain's test results were negative for carbon monoxide, hydrogen cyanide, alcohol, and other licit and illicit drugs. Test results of the first officer and flight attendant were negative for licit and illicit drugs except alcohol. A liver sample from the first officer tested positive for alcohol at a level of .06 percent, and a bile sample from the flight attendant tested positive for alcohol at a level of .07 percent. Evidence of heat coagulation was noted in all tissue samples of the first officer and flight attendant that were examined. Heat exposure can accelerate putrefaction and post-mortem production of alcohol. A second testing of samples by another laboratory found higher levels of alcohol, but the laboratory director noted that putrefaction of the samples had occurred prior to their arrival at the laboratory.

1.13.2 Maintenance Personnel

During the on-site portion of the investigation, a request was made by the Safety Board for urine and blood samples from the 12 persons who had been involved in the maintenance of the airplane on the evening and midnight shifts on September 10 and 11, 1991. They included two mechanics, two supervisors, and an inspector from the second or evening shift; and four mechanics, two supervisors and one inspector from the third or night shift.

Blood and urine samples were obtained by the airline's office of Human Resources and Drug Abatement. The samples were obtained for 11 of the individuals during the night work period of September 14 through 15, and from the remaining person the following morning, September 15, 1991. The samples were provided to the Safety Board and were tested. All test results were negative for alcohol and drugs of abuse.

1.13.3 Air Traffic Control Personnel

About 1300, September 11, 1991, 2 hours after the accident, the Safety Board asked the FAA for urine and blood samples from the air traffic controllers at the Houston ARTCC. Samples were voluntarily provided by the two controllers who last spoke to the flightcrew. Also, samples were provided by the controllers' two supervisors. The samples were submitted and retained under Safety Board authority.

Because there was no evidence of air traffic controller involvement in the accident, the samples obtained from the two controllers and their supervisors were not analyzed. The samples were subsequently returned to these individuals.

1.14 Fire

There was a fire in flight, as well as after ground impact. This was confirmed by eyewitnesses and wreckage examination.

The horizontal stabilizer and about 1/3 of the upper vertical stabilizer had separated from the airplane before ground impact. The horizontal stabilizer, with about 3 feet of the uppermost vertical stabilizer still attached, contained some light soot deposits. A broken edge of composite material that spanned the upper surface of the horizontal stabilizer, along the center line of the horizontal stabilizer, showed a small burned area. Although there were bits of molten aluminum splattered on the lower two thirds of the vertical stabilizer, there was no evidence of molten aluminum splatters on the upper portion of the vertical stabilizer or the horizontal stabilizer.

The lower two thirds of the vertical stabilizer that remained attached to the fuselage was found in place in the main wreckage. Bits of molten aluminum were found splattered on the left surface of this lower portion of the vertical stabilizer.

Approximately the lower half of the primary and secondary rudder control surfaces that remained attached to the lower portion of the vertical stabilizer showed heat damage, including molten aluminum splatters. The upper half of the rudder control surfaces, which was found as a unit in a field approximately 4/10 mile west of the main wreckage, showed no evidence of smoke deposits or fire damage. The upper and lower sections of the rudder control surfaces were placed together, and a clear demarcation line was seen where the rudder surfaces had broken.

1.15 Survival Aspects

The accident was not survivable.

The police chief learned about the accident about 1010, and the first of two 350 gallon, four-wheel drive mini-pumper fire trucks arrived at the accident site around 1020. The fire was nearly extinguished when the first truck arrived, and limited effort was required to extinguish the remaining flames. In total, about 12 volunteer firemen and 6 ambulances responded to the crash.

1.16 Tests and Research

1.16.1 Airplane Performance

The airplane was flying to the northeast on a 44-degree heading at the time radar contact was lost at 1003:06 CDT. Figure 2| shows the radar-derived ground track of flight 2574, selected sounds from the CVR, and the wreckage distribution.

Figure 3 provides a closeup view of part of the ground track and wreckage distribution. The piece of airplane structure farthest from the main wreckage was the left side leading edge (LE) of the horizontal stabilizer. The LE was the first piece of structure along the flight's northeasterly ground track, preceding the next piece by roughly 1/2 of a nautical mile.

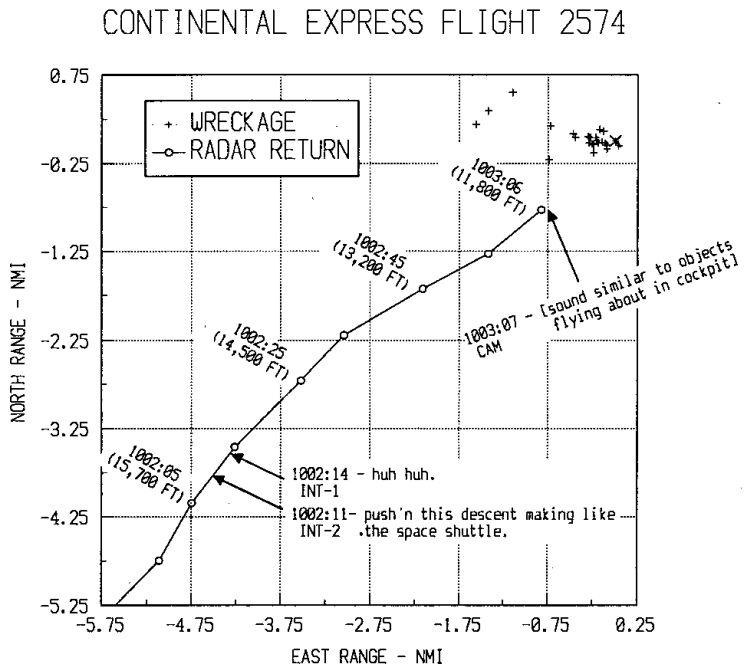

Figure 2.--Radar-derived ground track, CVR sounds, and wreckage distribution.

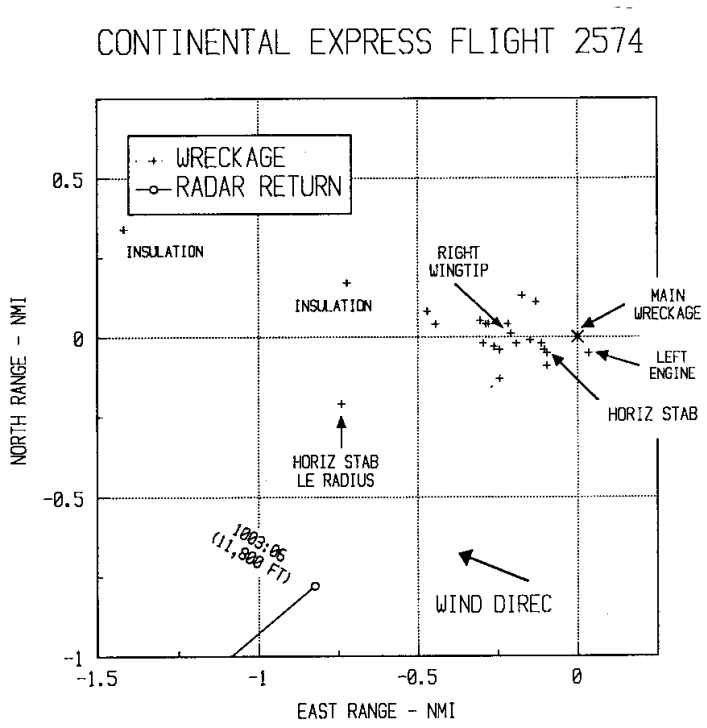

Figure 3.--Closeup view of part of ground track and wreckage distribution.

Figure 4 shows the radar-derived descent profile. The last radar contact occurred as flight 2574 was descending through 11,800 feet. The radar-derived rate of descent during the final minute was approximately 4,000 feet-per-minute, which is consistent with FDR data from the airplane.

The Safety Board used FDR data, CVR data, and engineering calculations from Embraer to study the motion and breakup of the airplane during the accident sequence. The flight dynamics of the accident were simulated by Embraer at the request of the Safety Board. Flight parameters at the time of the in-flight upset, including airspeed, altitude, acceleration, and airplane attitude, were examined. The leading edge separation from the left horizontal stabilizer was examined, as was the separation of the entire horizontal stabilizer from the airframe. The known flight characteristics of the airplane, before the sudden inflight changes, were used to examine the events during the accident sequence.

The FDR data show that the airplane was descending through 11,500 feet (pressure altitude) at 260 knots indicated airspeed (KIAS) when it abruptly pitched down and entered a steep dive. The airplane was 12 knots below the upper limit (272 KIAS) of the EMB-120 airspeed envelope when the upset occurred. The FDR data showed that a negative load factor of at least -3.375 g was reached about 1 second after the upset, with a corresponding decrease in airplane pitch attitude. The peak negative acceleration is unknown because the FDR's recording limit of -3.375 g was reached. The normal acceleration then fluctuated between about -0.6 and -2.4 g until the lower recording limit was reached again, 6 1/2 seconds after the upset began. At that point, the data show the airplane descending through 9,500 feet at 280 KIAS.

During the first 6 1/2 seconds after the upset began, the data showed a roll of 10 to 15 degrees right wing down and a nose-left heading move from 52 to 33 degrees. During the same period, the lateral acceleration was as much as 1/2 g.

After the 6 1/2 second period, the airplane abruptly rolled to the right more than 160 degrees in 1 second. During that 1 second, the airplane pitch attitude reached the minimum recorded value of -86 degrees, and then it began increasing. Normal acceleration went from about -0.5 to +2 g. Lateral acceleration went from about - .05 g to the recorded positive limit of +1 g, stayed at that limit for several seconds, and then went to the negative limit of -1 g before the FDR ceased operation.

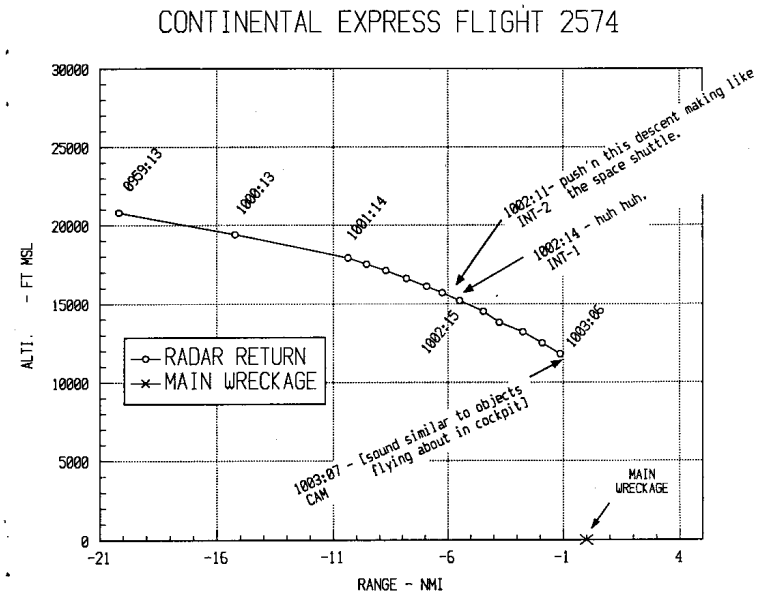

Figure 4.--Radar-derived descent profile.

According to Embraer EMB-120 engineering data, the horizontal stabilizer angle of attack in steady-state flight at 260 KIAS is -2 degrees. An aerodynamic stall (loss) of the left side horizontal stabilizer reduces the downward lift vector (downforce) at the tail (which is needed to maintain steady flight), and a large nose-down pitching moment is produced that leads to a negative wing stall. Calculations show that the wing stall occurs within 1 1/2 seconds of the tail stall, with a peak negative acceleration of about -5 g.

Two dynamic flight simulations were conducted in an attempt to determine whether the data obtained from the FDR would match the circumstances of a sudden loss of the left stabilizer leading edge or a sudden loss of the entire horizontal stabilizer. The results of the two simulations are shown in Appendix H. Because of limitations in available FDR data and the highly dynamic motion, the flight dynamic predictions could only examine the first 1 1/2 seconds of the flight after the upset.

Neither simulation could precisely duplicate the performance of the accident airplane as recorded by the FDR. The first simulation (that assumed a sudden loss of the left horizontal stabilizer leading edge) showed a less severe pitch down and negative load factor, while the second simulation (that assumed loss of the entire horizontal stabilizer) was more severe than the FDR data recorded for the accident flight. The first simulation incorporated a loss of downforce and increase in drag that are estimated and consistent with standard aerodynamic practices. Because lift from the horizontal stabilizer was directed downward, a transient rise in normal acceleration occurred after the leading edge detached and the downward lift was lost. In the first simulation, this "g" increase was equivalent to 1/2 of the downforce produced by the horizontal stabilizer. A transient rise in acceleration also exists in FDR data. However, lift and drag forces would change significantly during the dynamic motion of the airplane and would be virtually impossible to duplicate exactly in an engineering simulator.

Calculations made by Embraer of the lift required from the horizontal stabilizer during both postmaintenance flights show that the peak stabilizer downforce occurred at the time of upset on the accident flight. The maximum downforce produced by the horizontal stabilizer during the previous flight was at least 30 percent lower than that achieved just prior to the accident.

Embraer was asked to provide the Safety Board with a structural analysis report to evaluate the effects of airloads on the airplane structure after separation of the left horizontal stabilizer leading edge. The calculations showed that the predicted airloads on the horizontal stabilizer and vertical stabilizer structure for a loss of the leading edge did not exceed the maximum allowable load for the vertical and horizontal stabilizers.

The airspeed experienced at the time of the in-flight breakup, 260 KIAS, while below the manufacturer's maximum allowable airspeed of 272 KIAS, was the highest airspeed experienced on either flight following the maintenance. The highest airspeed recorded on the FDR on the first flight of the day, from IAH to LRD, was 216 KIAS.

1.17 Additional Information

1.17.1 Maintenance Records Review--General

The Safety Board examined in detail the recent maintenance history of N33701 related to the work conducted on the horizontal stabilizer. This effort involved a review of paperwork and procedures and extensive interviews of maintenance personnel associated with the work on the airplane the night before the accident. Additionally, the past full year of records were examined for items related to airworthiness directive (AD) actions and actions related to engine/propeller and flight control discrepancies. Further, the Safety Board reviewed Continental Express' FAA-approved General Maintenance Manual (GMM) and its required inspection item (RII) program.

No discrepancies were noted with AD compliance. Certain discrepancies were noted with respect to actions taken during a past replacement (April 24, 1991) of the right elevator on N33701, and as the result of an overtorque on the No. 1 engine (September 24, 1990). See sections 1.17.5 and 1.17.6 for additional details.

1.17.2 General Maintenance Manual (GMM)

The Continental Express GMM had FAA-approved procedures. GMM 1, Section 1, Paragraphs 1-6, states that

> *personnel performing maintenance will follow and be familiar with the instructions as outlined herein....Instructions and information, contained herein, bring Continental Express into compliance with the appropriate Federal Aviation Regulations. For this reason, it is essential that the contents be followed.*

GMM 1, Section 3, Paragraph 10, specifies that it is imperative for maintenance/inspection forms to be completed to ensure that no work item is overlooked. Such work includes the completion of maintenance/inspection shift turnover forms, so that oncoming supervisory personnel can be made aware of complete/incomplete work, and the documentation of incomplete work that the mechanic can note on the reverse side of the M-602 work cards. GMM 1, Section 5, Paragraph 7, specifically addresses several methods to ensure proper turnover during shift changes. These methods include briefings by mechanics to supervisors and briefings by outgoing supervisors to incoming supervisors.

The GMM contained provisions for a lead mechanic position in the organizational structure of the maintenance department. That position was not filled at the IAH maintenance base. According to the FAA maintenance inspector responsible for oversight of the Continental Express maintenance facilities, the lead mechanic position was identified in the organizational structure of one of the merger airlines. That position did not exist at the other merger airline. Instead, the supervisor was assigned to perform the functions assigned to the lead mechanic. Therefore, the lead mechanic position did not exist at the IAH maintenance base and, according to the FAA inspector, would not be considered a deviation from or violation of the provisions of the GMM for the Houston base.

1.17.3 Horizontal Stabilizer Maintenance

The review of the maintenance records for N33701 revealed that on August 26, 1991, during the airline's fleet-wide campaign to examine aircraft deice boots for winter operation, a quality control inspector had noted both leading edge deice boots as "watch list" items on M-602 work cards because of "dry rotted pin holes entire length" [of the boots]. On September 10, 1991, the night before the accident, Continental Express' Maintenance Control office scheduled both horizontal stabilizer leading edge deice boots on N33701 for replacement.

A series of interviews was conducted from September 13 through 16, 1991, and from October 22 through 24, 1991, with airline maintenance personnel, inspectors, and supervisors who were working the night before the accident. These personnel worked on the airplane on the second or "evening" shift and third or "midnight" shift. During the first series of interviews, seven mechanics, four maintenance supervisors, and three quality control inspectors were interviewed. During the second series, one mechanic, one inspector, and two supervisors were reinterviewed; and two senior directors and two FAA principal maintenance inspectors were interviewed for the first time.

The interviews revealed that the night before the accident, the airplane was pulled into the Continental Express hangar at IAH during the second shift at about 2130 hours for scheduled maintenance. The scheduled maintenance included the removal and replacement of both the left and right horizontal stabilizer deice boots.

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 from the stabilizer. Normally, while still attached to the stabilizer, the old deice boot would be stripped from the composite structure of the leading edge, the deice fluid lines would be disconnected, and the leading edge would be removed and a new deice boot bonded on. Then, the leading edge/deice boot assembly would be reinstalled on the horizontal stabilizer by means of approximately 47 attaching screws for each of the top and bottom sides of the assembly.

Two second shift mechanics, with the assistance of an inspector, gained access to the T-tail, which was about 20 feet above the ground, by means of a hydraulic lift work platform. The work was assigned by the second shift supervisor who took charge of N33701. The two mechanics removed most of the screws on the bottom side of the right leading edge and partially removed the deice boot bonded to the front of the right side leading edge.

The inspector who had climbed on top of the T-tail had 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 bottom screws that continued holding the horizontal 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.

The right leading edge assembly was removed from the horizontal stabilizer following a shift change by third shift mechanics. A new deice boot was bonded to the front of the leading edge at a work bench inside the hangar. During the third shift, the accident airplane was pushed out of the hanger to make room for work on another airplane. There was no direct light placed on the airplane as it sat outside the hangar. Work on the horizontal stabilizer was resumed outside. The third shift mechanics reinstalled the right side leading edge assembly. They used new and used screws to attach the top and bottom of the assembly to the right horizontal stabilizer.

The second shift work on N33701 was indicated on the second 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. The M-602 work cards had originally been assigned to the third shift for completion, but the second shift supervisor, who was assigned to N33701, elected to start work on the deice boots to assist the third shift with the workload. In addition, he did not issue the M-602 work 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 cards that would have informed the third shift supervisor and third shift mechanics that work had been started by the second shift on both the left and right horizontal stabilizer 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 the deice lines on the right side of the horizontal stabilizer. He stated that he was not aware of the removal of the screws from the top of the left leading edge assembly of the horizontal stabilizer. In the dark outside the hangar, he did not see that the screws were missing from the top of the left side leading edge assembly for the horizontal stabilizer.

Based on information gathered from interviews and statements, the following significant maintenance events took place the night before the accident:

2000:	The second shift supervisor, who was in charge of a "C" check on another airplane, and another supervisor normally assigned to the flight line but who was to supervise the

work on N33701, discussed bringing N33701 into the hangar. [There were two supervisors on the second shift. One supervisor was normally assigned to the flight line, but he took charge of the maintenance on N33701. The second supervisor was in charge of a C check on another airplane.]

2100: The supervisor who took charge of N33701 told a second shift mechanic to remove both deice boots from N33701.

2130: N33701 was brought into the hangar by the second shift supervisor, who was responsible for the C check on another airplane. A second shift inspector informed the other second shift supervisor, who was now responsible for N33701, that he would volunteer to assist mechanics with the boot changes.

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

2200: The second shift supervisor responsible for N33701 observed two mechanics and the second shift inspector kneeling on the right stabilizer 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 deice boot.

The third shift supervisor, who was working the hangar, asked the second shift supervisor (who was responsible for the C check on another airplane) if work had started on the left stabilizer. The third shift supervisor observed the supervisor look up at the tail of N33701 and state "No."

The third shift supervisor, who was working the hangar, told the second shift supervisor (who was responsible for the C check on another airplane) that he would be able to change the right deice boot that evening, that the left deice boot change could be made on another night, and that he would return the left replacement boot to stock. The second shift supervisor took the right replacement boot and placed it on a work bench.

2005: The third shift inspector arrived early for work and saw that the majority of the right deice boot had been removed. He reviewed the inspector's turnover form and found no writeup on N33701 because the second shift inspector, who had removed the upper screws, had not yet made his log entries.

2215: A third shift mechanic clocked in and went to the break room to chat with friends until the start of his shift at 2230.

Shift Change

2230: The second shift inspector, who removed the upper screws from the leading edges of both stabilizers on N33701, filled out the inspector's turnover form with the entry, "helped the mechanic remove the deice boots." He then clocked out, and left for home. The inspector later stated that he placed the screws that he removed from the top row of the left and right sides of the horizontal stabilizer in a bag and that he left the bag on the manlift.

One of the two mechanics, who was helping with the boot change on N33701, stopped working and returned to airplane 724 to finish work that he had started earlier in the shift.

A third shift mechanic was informed by the third shift supervisor that he was assigned to do the line check on N33701, and that he needed to reposition N33701 outside the hangar. N33701 was then moved outside the hanger.

The second shift mechanic, who had been removing the deice boot on N33701, gave a verbal turnover to the second shift supervisor (who was responsible for the C check on another airplane). The mechanic was instructed by the supervisor to give his turnover to a third shift mechanic. After giving a turnover to a third shift mechanic, the second shift mechanic locked up his tools and clocked out.

The third shift mechanic, who received the turnover from the second shift mechanic, was not assigned later to N33701. He later stated that he recalled seeing the bag of removed screws on the manlift. The third shift mechanic gave a verbal turnover to another third shift mechanic, who later did not recall receiving a turnover and stated that he did not see any bagged screws.

Another third shift mechanic arrived at the hangar and was informed by the third shift supervisor, who was working the hangar, that he was assigned to N33701's boot replacement and that he should talk to the second shift supervisor to find out what had been accomplished. There was no discussion regarding which of the two second shift supervisors that the third shift mechanic should talk to. The mechanic talked to the second shift supervisor in charge of the C check on another airplane.

The third shift mechanic then asked the second shift supervisor (who was responsible for the C check on another airplane) what had been done on N33701 during the second shift. The mechanic observed the supervisor point to the tail of N33701 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 he would have 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 N33701.
2300:	The second shift supervisor responsible for N33701 left work about this time. 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 before he left for home.
2330:	The second shift mechanic who helped with the removal of the right boot clocked out and left for the evening.

Subsequently, the airplane was cleared for flight. The first flight was a passenger flight from IAH to LRD at 0700. There is no evidence from the morning's preflight that the flightcrew knew of any of the work performed on the horizontal stabilizer. Moreover, the FARs and airlines did not require them to be informed of such work.

The flight from IAH to LRD was without incident. Shortly after the accident, a passenger, who had been on the flight from IAH to LRD, informed Safety Board investigators that he was awakened on the flight to LRD by vibrations that rattled his beverage can on the meal tray in front of him. Accordingly, he asked the flight attendant if he could move to another seat. The passenger did not inform the flight attendant or any other crewmembers about the vibrations. Others passengers on that flight, some of whom had flown on that model airplane previously, did not recall unusual vibrations. The accident took place on the return trip from LRD to IAH.

1.17.4 Required Inspection Items (RIIs)

Continental Express' GMM 1 Section 5, states that

> *Continental Express has established a list of items that requires a concentrated inspection (RII) on any work performed on those items. This list includes items that could result in a failure or malfunction that could endanger the safe operation of the aircraft, if not properly installed or if improper parts or materials are used.*

On page 5-5, Paragraph 2, "Designated [required inspection] Items" the item "Stabilizers" is listed. Also, 14 CFR 135.427 states

> *A designation of the items of maintenance and alteration that must be inspected (required inspections) including at least those that could result in a failure, malfunction, or defect endangering the safe operation of the aircraft, if not performed properly or if improper parts or materials are used.*

Continental Express' management and quality control inspectors stated that the removal and replacement of the horizontal stabilizer leading edge deice boots were not RIIs. RIIs are required to be inspected by a quality assurance inspector. However, the M-602 maintenance work order cards, used the night before the accident to assign the work to change both the left and right horizontal stabilizer deice boots, had the RII "Yes" block circled. Further, the completion of the deice boot change, the removal of the used deice boot, and the bonding of a new boot to the right side leading edge assembly were signed off by a quality control inspector on the third shift. However, the inspector stated that he knew that the boot was not an RII and therefore conducted only a cursory walk around the tail without inspecting the final installation of the leading edge/deice boot.

Embraer stated that the deice boots and leading edges, as assemblies, were RIIs and were part of the larger stabilizer assembly, listed in the FAA-approved operator's GMM as an RII. The manufacturer noted by letter (See appendix G) that the subject assembly met the operational requirement of the FAA for a RII, in accordance with 14 CFR 135.427(b)(2).

Continental Express' management maintained that the leading edge/deice boot assembly was a separate assembly and that if the manufacturer or FAA had wanted the assembly treated as an RII or critical item they should have made that clear.

1.17.5 Right Elevator Replacement

The maintenance records for N33701 revealed that on April 24, 1991, the right elevator was removed from airplane 708 because of damage from a lightning strike. Airplane 708 was subsequently returned to service following the installation of a replacement right elevator. The damaged elevator was repaired on April 27, 1991, and was installed on N33701 on May 2, 1991. The elevator had been repaired using approved technical information supplied by Embraer's Structural Repair Manual (SRM), section 55-20-01. The SRM referred the mechanic to section 51-62-01 of the SRM, which contained procedures for statically balancing the elevator, after the repair had been made. The mechanic who balanced the elevator following its repair stated that he had read the balancing procedures contained in the SRM.

SRM sections entitled "Control Surface Static Balancing" and "Equipment and Consumable Material for Balancing" had complete descriptions of control surface static balancing, a table of equipment used for control surface balancing, a balancing stand with an adjustable support, and included the Ground Service Equipment (GSE) Number 094 and a diagram of the necessary equipment.

The investigation revealed that the approved balancing equipment was available but apparently misplaced and was not used for the balancing of the elevator that was eventually installed on N33701. The mechanic stated that he used "homemade" balancing blocks on a level table and visually confirmed the balance of the elevator. Embraer stated that it recommends the use of the equipment listed in the SRM for balancing control surfaces; however, in emergency situations, jack assemblies could be used, provided that the rotational axis of the control surface is horizontal. The FAA's Principal Maintenance Inspector (PMI) assigned to Embraer was asked by accident investigators if the procedure used by the mechanic was approved by the FAA, and he replied "No."

Embraer was asked what effects an unbalanced elevator would have on the airplane. Embraer replied that the repair to the right elevator on the accident airplane would "represent [a] less than 1% out of balance condition, which could be regarded as a negligible effect."

1.17.6 No. 1 Engine Overtorque

On September 25, 1990, the left engine and propeller on N33701 experienced an overtorque to 141 percent. After performing the required initial inspection of the engine, per the Pratt & Whitney Maintenance Manual 72-00-00, Revision 6, the airplane was issued a ferry permit to return to Houston for further detailed inspection. As a result of the overtorque, the left propeller was changed on September 28, 1990, per the Hamilton Standard Maintenance Manual. The engine was inspected in accordance with Pratt & Whitney Canada Service Information Letter PW-123, issued on March 9, 1990. On September 28, 1990, the airplane was returned to service.

The Pratt & Whitney maintenance manual required, in addition to the initial inspection, the following: repetitive inspections of the chip detector/filter element after approximately 10 hours or 1 day of operation, and thereafter at approximately 25 hours, 50 hours, and 100 hours, respectively, with the last check at approximately 250 hours or at the next A check. If no ferrous material was found after these checks, the engine could remain in service without further special maintenance action and subject to local airworthiness authority approval.

The review of the maintenance records revealed that certain procedures recommended by the Pratt & Whitney maintenance manual were not followed. For example, there was no record that the required repetitive chip detector inspections were performed. Continental Express stated that it had performed a continuity check of the chip detector circuit at every line check, which occurs less frequently than every 2 days (about 175 times in the past year). Continental Express added that the line check method would have detected the presence of metal in the detector. There were no reports of chip detector problems during that period. Continental Express also stated that it had performed eight A checks during the same time period, in which the engine scavenge and main filters are checked. There was no record of metal particle contamination.

Additionally, the required engine log book entry regarding the overtorque event was not found. Also, there was no record that the PMI had been requested to provide or had granted the required approval for the engine to remain in service, although Continental Express had notified the PMI of the event.

2. Analysis

2.1 General

Weather was not a factor in the accident. ATC services were properly conducted and were not a factor in the accident. The flightcrew was properly qualified and certified to conduct the flight. The performance of the flightcrew was not a factor in the accident. The accident was nonsurvivable because of the severe impact forces.

The examination of the wreckage confirmed that the airplane had experienced an in-flight fire that occurred after, not before, the in-flight breakup. Evidence to support this conclusion includes the fire damage pattern on the empennage pieces. The fire pattern shows that the leading edge of the horizontal stabilizer and the upper portion of the vertical stabilizer with the upper rudder surfaces attached separated from the airframe before the in-flight fire occurred. Although the horizontal stabilizer experienced minor soot deposits and heat damage, it separated from the airframe before the fire damage became more significant. The lower portions of the vertical stabilizer and lower rudder surfaces that remained attached to the airframe until ground impact experienced significant fire damage. Further, the lack of fire damage on the left engine suggests that this engine separated early in the breakup sequence when the left wing failed. The failure of the left wing released fuel that probably led to the in-flight fire.

The passenger seat that was ejected from the cabin at ground impact suggests that the fire did not progress into the cabin area before impact. This conclusion is supported by the absence of soot deposits in the respiratory tract of the occupants, and the absence of elevated carboxyhemoglobin in the tissues of the occupants.

The FDR data and examination of the wreckage revealed that the flight control systems, engines, and propellers were operating normally before the extreme attitude changes of the airplane. Consequently, engine and propeller malfunctions were not a factor in the accident.

The Safety Board's analysis of this accident included an examination of the circumstances that led to the loss of the left stabilizer leading edge, including: flightcrew performance related to the accident; the maintenance and inspection conducted by Continental Express the night before the accident; the management of the Continental Express maintenance department; the FAA approval and oversight of the Continental Express maintenance program; and the procedures for establishing RIIs by the aircraft manufacturer, the airline, and the FAA.

The Safety Board's analysis also examined the aerodynamic and structural failure aspects related to the dynamics of the airplane after it lost the left stabilizer leading edge.

2.2 Aerodynamic and Structural Failure Aspects

The Safety Board believes that the airplane experienced the following sequence of events during the final moments of flight. The airplane was descending at 260 KIAS, which was well within its operating envelope, the wings were level, both engines were operating normally, and the pitch attitude was 10 degrees nose down. As the airplane descended through 11,500 feet, the leading edge of the left horizontal stabilizer separated from the airframe. The left horizontal stabilizer leading edge was the first piece of wreckage found along the wreckage path, preceding the next piece by almost 1/2 mile. This indicates that it was the first piece to separate from the airplane. The loss of the leading edge exposed the front spar of the left side of the horizontal stabilizer to the airstream, and an aerodynamic stall occurred that greatly reduced the downforce produced by the horizontal stabilizer. The reduction in downforce created a large nose-down pitching moment, and the airplane pitched down immediately. A peak load factor of approximately -5 g was reached at the end of only 1 second.

The airframe remained intact (minus the leading edge), and the load factor fluctuated around -2 g, for approximately 6 1/2 seconds. The airplane pitch attitude decreased to 68 degrees nose down, airplane heading moved 20 degrees nose left, and a 15 degree right roll attitude was reached at the end of this period. The airplane's altitude was 9,500 feet, and it was flying at an airspeed of 280 KIAS. A second peak in negative load factor was then experienced, and the Safety Board believes that the left wing failed and the right wing tip detached at this point.

The airplane then rolled to the right at a roll rate exceeding 160 degrees per second. The Safety Board believes that the lift produced by the intact right wing produced the extreme roll. The high airspeed and roll rate created large airloads on the airplane's structure. The Safety Board believes that excessive airloads induced by the high airspeeds and/or roll rate caused the horizontal stabilizer and left engine to separate from the airframe. The airplane then entered a spin to the right, fell uncontrollably toward impact, its pitch attitude oscillating between approximately -40 degrees and +40 degrees.

To recreate this sequence, the Safety Board relied on the substantial amount of evidence obtained from the wreckage, CVR, and FDR. Flight dynamics and structural simulations by Embraer provided additional data for use in the investigation.

The Safety Board analyzed the airloads that were applied to the partially secured leading edge on the accident airplane. The atmosphere was calm; therefore, gust loads were probably not a factor in the separation of the leading edge. Aerodynamic lift and drag both produce loads on the horizontal stabilizer structure. In general, aerodynamic loads are significantly greater at higher airspeeds since the dynamic pressure of the airstream varies directly with the square of airplane velocity.

Aerodynamic drag exerts a force on the airplane that is opposite to the direction of motion and parallel to the relative wind. Therefore, aerodynamic drag created an aft load on the horizontal stabilizer structure of the accident airplane. This force compressed the partially secured leading edge against the front spar of the stabilizer structure and helped to keep the leading edge in place. However, aerodynamic lift is also an important factor in the determination of airloads acting on the stabilizer.

The horizontal stabilizer in this case provides negative, or downward, lift to balance the pitching moment of the wings, engines, and fuselage. Airplane nose pitch attitude is controlled up or down by deflecting the elevator attached to the rear of the horizontal stabilizer. The lift force required at the horizontal stabilizer to establish trimmed flight is a function of many factors, such as the center of gravity, engine thrust, airspeed, and airplane configuration. The airplane is described as being "trimmed" in pitch if the sum of the pitching moments created by these factors is equal to zero. Calculations that defined the horizontal stabilizer lift required (downward) for the two postmaintenance flights on N33701 showed that the peak download occurred at the time of the accident flight upset. The calculations also showed that the maximum downforce produced during the first flight was at least 30 percent lower than that achieved at the time of the upset.

It is apparent that the airloads did not appreciably deflect the leading edge during the first postmaintenance flight. However, the aerodynamic download at 260 KIAS during the accident flight probably deflected the partially secured leading edge downward to the point where the combination of down and aft loads tore the leading edge from the airplane. At the time of the upset, the airspeed was high but within normal operating limits. The FDR data show an initial transient small increase in load factor that is consistent with the loss of 1/2 of the downward force immediately before the large nose-down pitching occurred.

Despite the limitations of flight dynamics predictions, airplane movements during the first 6 1/2 seconds after the upset were consistent with the forces expected following a loss of the left side horizontal stabilizer leading edge. The FDR recorded a nose-left heading change and lateral acceleration that are consistent with an airplane sideslip caused by a drag imbalance between the left (higher drag) and right sides of the airplane. The higher drag on the left side of the airplane was most likely because of the missing leading edge of the left horizontal stabilizer spar. The airplane also reached and maintained 10 degrees to 15 degrees of right roll during the 6 1/2 second interval after upset. The flight dynamics

simulation produced a right roll after the upset because of the unbalanced downforce produced by the asymmetrical horizontal stabilizer.

The evidence shows that the airframe remained intact and that the load factor fluctuated around -2 g for about 6 1/2 seconds before a second peak in negative load factor was evident, at which point the left wing structure failed negatively, and the airplane rolled violently to the right at a roll rate exceeding 160 degrees per second. The roll was caused by the lift of the intact right wing. This maneuver created additional extreme airloads on the entire airplane structure, resulting in failure and separation of the horizontal stabilizer and left engine.

The airloads on the horizontal and vertical stabilizers prior to the wing failure, as calculated by Embraer, did not exceed the maximum allowable. This information is consistent with the FDR data and physical evidence that the empennage did not fail until after the failure of the left wing. Witnesses reported seeing the airplane in a left spin prior to ground impact. Although the FDR data show the airplane in a right spin following wing failure, the recording ends about 13 seconds before impact.

In summary, the Safety Board concludes that the FDR data, engineering simulation, and examination of the wreckage confirm that the accident sequence was initiated by the loss of the left leading edge of the horizontal stabilizer.

2.3 Flightcrew Preflight Performance

The Safety Board found no evidence that the two pilots were informed of the work that had been performed on the horizontal stabilizer the night before the accident. Of course, if the pilots had wanted to review the maintenance records for the airplane, the records would undoubtedly have been made available to them. However, there was no indication of any work on the stabilizer leading edges in the pilot's airplane log book, and no indication has been found that the flightcrew was informed of any of this work, even though the work was on a critical assembly of the airplane--the horizontal stabilizer leading edges.

The Safety Board is aware that the work performed on the horizontal stabilizers was considered scheduled maintenance and was not normally noted in the pilot's airplane log book. Further, there are no regulatory provisions for pilots to be made aware of routine maintenance work, regardless of its complexity. However, the Safety Board believes that a study should be undertaken on the feasibility of developing a means to advise flightcrews about recent maintenance actions, both routine and nonroutine, of the airplanes they are about to fly, so that they have the opportunity 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. In this case, if the flightcrew had been informed of the previous night's work on the airplane, they might have, with the advantage of morning daylight, lent a crucial hand in checking the work.

The top of the horizontal stabilizer on the airplane's "T-tail" is about 20 feet above the ground. Therefore, the flightcrew could not have seen the area of the missing screws on top of the leading edge/deice boot during their normal preflight inspection. However, if they had been informed of the maintenance, they might have discussed the work with maintenance personnel and requested them to conduct a visual inspection of the stabilizer's upper surface. Because the flightcrew was unaware of the previous night's work on the airplane, the possibility of having another set of eyes observe the work was eliminated.

The Safety Board believes that the FAA should require airlines to establish procedures to inform pilots of all significant maintenance on airplanes before flight. Such information would allow pilots to be more alert to potential unsafe conditions when they conduct preflight inspections. The redundancy provided by such a requirement would be important for many critical maintenance items.

2.4 Maintenance Factors

The evidence is clear that the events during the maintenance and inspection of N33701 the night before the accident were directly causal to the accident. Several errors were made by the individuals responsible for the airworthiness of the airplane. The Safety Board believes that the reasons for the errors and the overall failure of the maintenance program are complex and are not simply related to a single failure by any single individual. Consequently, the Safety Board's analysis of the maintenance and inspection program concentrated on the systemic reasons for the accident, as well as the specific errors made by the individuals concerned.

The Continental Express GMM had FAA-approved procedures for shift turnovers. These procedures included briefings by mechanics to supervisors, briefings by outgoing supervisors to incoming supervisors, completion of maintenance and inspection shift turnover forms (so that oncoming personnel would be aware of incomplete work), and the documentation of incomplete work that would be noted by the mechanic on the reverse sides of M-602 work cards. In fact, the Safety Board found no specific deficiencies in the GMM, other than the fact that the GMM did not delineate or identify specifically the horizontal stabilizer leading edge deice boots as an RII. Only the major structural items were listed. However, this deficiency alone did not cause the accident, and it is not unique to Continental Express. This issue is discussed further in section 2.5. The Safety Board concludes that the GMM contained clear procedures, which, if followed, could have prevented the accident.

The Safety Board concludes that the upper row of screws that had been removed from the leading edge of the left horizontal stabilizer was undetected because the approved procedures in the GMM were not followed by the maintenance, supervisory and quality control personnel directly charged with evaluating the airworthiness of N33701 before it was returned to service. The following are examples of substandard practices and procedures and oversights by individuals, who had an opportunity to prevent the accident:

Second Shift Supervisor Responsible for N33701

The second shift supervisor responsible for N33701 failed to solicit an end-of-shift verbal report (shift turnover) from the two mechanics he assigned to remove both horizontal stabilizer 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 also failed to give the M-602 work 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 Safety Board believes that the accident would most likely not have occurred if this supervisor had solicited a verbal shift turnover from the two mechanics he had assigned to remove the deice boots, had passed that information to the third shift supervisor, had completed the maintenance shift turnover form, and had ensured that the mechanics who had worked on the deice boots had filled out the M-602 work cards so that the third shift supervisor could have reviewed them.