Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A04O0188

RUNWAY OVERRUN

US AIRWAYS EXPRESS
EMBRAER EMB-145LR N829HK
OTTAWA/MACDONALD CARTIER INTERNATIONAL AIRPORT
14 JULY 2004

Canada

Aviation Investigation Report

Runway Overrun

US Airways Express
Embraer EMB-145LR N829HK
Ottawa/Macdonald Cartier International Airport, Ontario
14 July 2004

Report Number A04O0188

Summary

The US Airways Express (Trans States Airlines) Embraer 145LR aircraft (Flight LOF3504, registration N829HK, serial number 145281) departed Pittsburgh, Pennsylvania, on a flight to Ottawa/Macdonald Cartier International Airport, Ontario, with two flight crew, one flight attendant, and 28 passengers on board. At 1720 eastern daylight time the aircraft landed on Runway 25 at Ottawa and overran the runway, coming to rest approximately 300 feet off the end of the runway in a grass field. There were no injuries. The aircraft sustained minor damage to the inboard left main landing gear tire. When the aircraft landed there were light rain showers. After the rain subsided, the passengers were deplaned and bussed to the terminal.

Other Factual Information

History of the Flight

The flight from Pittsburgh was uneventful. Approaching Ottawa, the aircraft was radar vectored around storm cells for a localizer back course Runway 25 approach to Ottawa/Macdonald-Cartier International Airport (MCIA). The aircraft was approximately 1.5 miles north of the Ottawa non-directional beacon (NDB) at 2000 feet above sea level (asl) and approximately 185 knots indicated airspeed (KIAS) when air traffic control (ATC) issued the instruction for the final turn to intercept the localizer. This resulted in a shortened final approach, since the NDB is only 4.1 nautical miles (nm) from the threshold of Runway 25. The aircraft was then cleared to land. Although the airspeed was high, the inboard spoilers, which could be deployed in flight as speed brakes, were not extended.

While attempting to capture the localizer, the aircraft drifted left and right of the localizer several times until on short final, less than one mile from the threshold. The flight crew had calculated the approach speeds as 133 KIAS for a flap 22 approach and 128 KIAS for a flap 45 approach. Because the aircraft was fast and on a high, shortened final approach, the flight crew prepared for a flap 22 landing. The maximum speed permitted for the flap 22 position is 200 KIAS, and for the flap 45 position, 145 KIAS. At approximately three miles from the threshold and 180 KIAS, the crew lowered the landing gear and selected flap 22. The airspeed decreased to 150 KIAS at one mile, and the aircraft crossed the runway threshold at 140 KIAS, 75 feet above airfield elevation (AAE). It then continued for 1675 feet before reaching 50 feet AAE. From 50 feet AAE to weight on wheels, the aircraft travelled approximately 2125 feet, and the weight on wheels speed was 120 KIAS. The landing, at approximately 1720 eastern daylight time,[1] was smooth with no abnormalities.

The aircraft was not equipped with thrust reversers; spoilers and wheel-brakes equipped with an anti-skid system were used to slow and stop the aircraft. On landing, all four spoilers deployed automatically and the brakes were applied, but the aircraft did not slow down as expected. About 11 seconds after weight on wheels, the captain questioned the pilot flying (PF) about slowing the aircraft, and the PF advised that the brakes were not working. The captain took control of the aircraft and immediately applied the brakes, initially with no effect. Deciding that a go-around would not be possible, the captain pushed the control column forward to ensure that the nose of the aircraft was down and continued to apply the brakes. The brakes started to work effectively 16 to 19 seconds after weight on wheels, and the aircraft began to slow down, but it could not be stopped on the runway. After the landing, the aircraft and runway were inspected and showed no physical signs of skidding or hydroplaning.

When hydroplaning occurs, the tires of the aircraft completely lose contact with the actual runway surface. They will continue to hydroplane until a reduction in speed permits the tires to regain contact with the runway surface. During total dynamic hydroplaning, the tire lifts off the runway and rides on a wedge of water, causing such a complete loss of tire friction that wheel spin-up will not occur. On wet runways, where there is not enough water to cause dynamic

---

[1] All times are eastern daylight time (Coordinated Universal Time minus four hours).

hydroplaning, viscous hydroplaning can occur. This term describes the normal slipperiness or lubricating action of water. Viscous hydroplaning does not reduce the friction to such a low level that wheel spin-up will not occur. On the other hand, reverted rubber hydroplaning can occur when a locked tire is skidded along a very slippery water- or slush-contaminated runway at any speed above about 20 knots, at which point the friction-generated heat produces steam and begins to revert the rubber, on a portion of the tire, to its uncured state.

Runway Data

Runway 07/25 at Ottawa MCIA is 8000 feet long, 200 feet wide, with a smooth asphalt surface. It was raining at the time of the occurrence and the runway was wet, but there were no indications of excessive quantities of standing water.

Flight Recorders

The flight data recorder (FDR) and cockpit voice recorder (CVR) were sent to the TSB Engineering Branch for analysis. The FDR data indicated that the aircraft was configured for the landing with 22° of flap. Weight on wheels occurred approximately 3800 feet from the threshold of the runway, and the aircraft travelled a further 4500 feet before coming to a complete stop. The vertical *g* data indicated that the touchdown was very smooth.

The hydraulic pressure for the braking system was plotted for the incident landing, and for the previous two landings, which had been conducted on dry runways. The brake pressure for all three landings started to rise at approximately six seconds after weight on wheels. The FDR records the brake pressures once per second. These records indicate that during the incident landing the brakes were active, although there were indications of low, fluctuating brake pressures, and the pressures did not rise above 500 psi until approximately 16 seconds after weight on wheels for the right brakes and 19 seconds for the left brakes. This rise in brake pressure coincides with an airspeed of approximately 94 KIAS. The pressures continued to rise over the next nine seconds to approximately 2450 psi for the right brakes and 900 psi for the left brakes, at which point the aircraft left the runway.

On the previous two landings the brakes were active and the pressures rose above 500 psi within the first ten seconds and continued to climb to a maximum of approximately 1000 psi over the next six seconds, at which point the pressures started to decrease. The occurrence aircraft was not equipped to record individual brake pedal positions—more recently produced aircraft are so equipped—so it was not possible to determine the amount of brake pedal deflection.

The longitudinal acceleration trace for the incident landing showed an increase in deceleration from $+0.08g$ to a constant deceleration of approximately $-0.08g$ until 15 seconds after weight on wheels, when the brake pressures started to rise. The deceleration then rose steadily to $-0.45g$ at which point the aircraft left the runway. On the previous landing the longitudinal deceleration increased to a maximum of approximately $-0.20g$ in the first 16 seconds after weight on wheels, and then started to decrease as the aircraft slowed.

While attempting to download the information from the CVR, it was found that the recorded data had been erased. The CVR was taken to the manufacturer's facility in Seattle and the data was successfully recovered. The CVR showed that 31 seconds before the end of the recording the CVR was powered down; the time recorded on the CVR from the aircraft UTC clock was 21:33:39. The CVR was then powered up again at 21:49:36, erased twice and then powered down six seconds after the second erase command was completed.

Erasure of cockpit voice recorders is prohibited in Canada by Canadian Aviation Regulation (CAR) 605.34 and in the United States by Federal Aviation Regulation (FAR) 125.227. In accordance with Transportation Safety Board Regulations (subsection 9 (1)) when a reportable accident or incident takes place, the owner, operator, master, and any crew member shall "…preserve and protect any evidence relative to the reportable accident or incident." The deliberate erasure of a CVR in an attempt to destroy evidence, would be an "offence punishable on summary conviction."[2] Everyone convicted of such an offence is liable, pursuant to the Criminal Code of Canada, to a fine of not more than $2000 or to imprisonment for six months or to both.

Flight Crew

The captain, who was the pilot non-flying, occupied the left seat. He held a valid airline transport pilot licence and had accumulated a total flying time of approximately 8000 hours, with 4300 hours on type.

The first officer, who was the PF, occupied the right seat. He held a valid commercial pilot licence and had accumulated a total flying time of approximately 1860 hours, with 900 hours on type. His experience as PF on Embraer aircraft without thrust reversers was limited to approximately five flights.

Weather

The 2100 aviation routine weather report (METAR) for Ottawa MCIA was as follows: wind 220° True at five knots, visibility 10 miles in light rain showers, overcast cloud layer at 2100 feet, altimeter setting of 29.55. There had been recent thunderstorms.

Performance Data (Weights and Charts)

The landing weight of the aircraft was calculated using the initial fuel load from the pilot reports, estimates of the passenger and cargo weights, and the FDR recorded fuel flow for the duration of the flight. The landing weight calculation is summarized in Appendix A. The landing weight was estimated to be approximately 41 000 pounds. The reference approach speed (Vref) for an Embraer 145LR at this weight is 132 knots for flap 22 and 127 knots for flap 45.

---

2 *Canadian Transportation Accident Investigation and Safety Board Act*

Landing field length data charts were available from the EMB-145 Aircraft Flight Manual (AFM) with distances given as factored and unfactored. The unfactored landing distance, as defined by FAR 25.125, is that distance between the aircraft when it is at 50 feet AAE and when it has come to complete stop on the ground. Based on the weight of the aircraft, nominal values are provided for both dry and wet runways. The factored runway length includes a safety factor as described in FAR 121.195. This builds a safety margin into the required runway length to allow for weather variations, landing technique, or a landing problem. The AFM safety factored landing distance for an aircraft landing weight of 41 000 pounds, with flap 22, landing on a wet runway with winds 230° at 5 knots was 6500 feet. The AFM unfactored landing distance for an aircraft in the same conditions is approximately 3900 feet. Assuming a typical touchdown target of 1000 feet from the threshold, this gives an AFM-derived ground roll distance of approximately 2900 feet. The actual ground roll distance of the aircraft as calculated from FDR data was approximately 4500 feet, including the 300-foot overrun. The FDR-derived ground roll exceeded the AFM nominal value by 1600 feet.

The occurrence flight FDR data indicated that the distance between the aircraft when it was 50 feet AAE to when it had come to a stop was 6625 feet.

Aircraft

The Embraer 145LR is available with or without thrust reversers. At the time of the occurrence, the operator’s Embraer fleet consisted of 22 aircraft fitted with thrust reversers and 17 aircraft without thrust reversers. Thrust reversers were not installed on the occurrence aircraft, and the aircraft was stopped using the wheel-brake system and the spoilers.

The aircraft was equipped with four spoilers, two on each wing. The two inboard spoilers can be deployed in flight as speed brakes to help slow the aircraft. For this to occur the aircraft must be configured with the flaps at 0° or 9°, and the thrust lever angles must be below 50°. With weight on wheels, all four spoilers deploy automatically when wheel speed exceeds 25 knots and both engine thrust lever angles are below 30°, or the N2 for both engines is below 56 per cent.

The brakes are controlled through the brake control computer, which has two independent circuits, one for the outboard brakes and one for the inboard brakes. Hydraulic system 1 and the essential DC bus 1 supply the brake system to control the outboard brakes, and hydraulic system 2 and the essential DC bus 2 supply the brake system to control the inboard brakes. The main components of the brake system are the following:

- brake control unit (BCU),
- brake pedal transducers (BPT),
- inboard and outboard brake control valves (BCV),
- brake shut-off valves (BSV),
- pressure switches,
- check valves,
- hydraulic fuses,
- pressure transducers, and
- brake assemblies.

The BCU contains all the circuitry to interface, control, monitor, and test the brake system components. This includes fault isolation and interfacing with the central maintenance computer and with the engine instrument and crew alerting system (EICAS).

The BCU activates the brake system after it senses either weight on wheels and wheel speed of 50 knots, or weight on wheels for three seconds. As soon as one of these requirements is met, hydraulic pressure will be available for braking. The amount of hydraulic pressure supplied for braking is proportional to brake pedal deflection through the BPT. If both pilots activate the brakes at the same time, the brake pressure is proportional to the pedals with the most deflection. Spring cartridges are installed in the BPT to provide a brake feeling to the flight crew; however, the spring cartridges do not provide brake feedback, they simply provide resistance at the brake pedals.

Anti-skid protection controls the amount of hydraulic pressure applied by the pilots on the brakes. Anti-skid provides the maximum allowable effort for the runway surface in use, minimizing tire wear and optimizing braking distance. To perform this function, the BCU computes the wheel speed signal from the four speed transducers. When one of the signals decreases below the average of the remaining wheels, skidding is probably occurring and that brake pressure is relieved. After that, wheel speed returns to the average speed and normal braking operation is restored.

For wheel speeds above 30 knots, the anti-skid system activates the locked-wheel protection. If the slower wheel speed is less than or equal to 30 per cent of the faster wheel speed, the skid control circuitry sends a corrective signal to the associated brake valve. The brake valve commands a full brake pressure relief to the associated wheel, allowing the wheel speed recovery. The 30 per cent tolerance between the wheel speeds permits some differential braking for steering purposes. For wheel speeds below 30 knots, the locked-wheel protection is deactivated, and the brake system actuates without the wheel-speed comparator. For wheel speeds below 10 knots the anti-skid function is deactivated.

Prior to the occurrence, there was a series of brake system component changes. This was done for company convenience; there was no prior indication of a brake problem on the occurrence aircraft. A full diagnostic check of the brake system was completed following the occurrence, and no anomalies were detected. As a precaution, the BCU was replaced and another full diagnostic was completed with no faults found. The occurrence BCU non-volatile memory (NVM) was later downloaded and four error codes were found. The BCU NVM does not record the time of the events. The manufacturer of this BCU indicated that the codes meant power had been interrupted. When error codes are generated, the messages BRK INBD INOP and/or BRK OUTBD INOP should be displayed on the EICAS. The error codes may also be generated during an APU start up, when a temporary loss of power in the BCU connectors could occur. However, this situation will not generate any EICAS messages because Embraer implemented delays on the EICAS during the APU start-up period. No EICAS messages were displayed during the incident landing roll.

Other Incidents

Two weeks after the occurrence flight, the same aircraft had a similar brake problem while landing in Montréal. At the time, it was raining and the runway had a smooth, asphalt surface. The brake system was checked thoroughly and no faults were found in the system. The aircraft was released back into service and no additional occurrences have been reported.

Analysis

A thorough examination of the aircraft's wheel-brake system was completed by the operator following this occurrence and the subsequent occurrence in Montréal, and no abnormalities were found. The analysis will deal only with the occurrence at MCIA.

The pilots were experienced overall and had flown the aircraft type for a good number of hours: the captain 4300 hours and the first officer 900 hours. They were more than likely aware that the aircraft was slightly higher and faster over the threshold than desired, the touchdown would be further down the runway than normal, and the runway was wet. With these conditions in mind, it is reasonable to assume that on landing, the crew would do everything possible to ensure that the aircraft stopped on the runway, especially fully applying the wheel brakes. However, the aircraft did not decelerate normally.

The AFM unfactored landing distance from 50 feet AAE to a full stop on a wet runway for this aircraft and the conditions of the landing was approximately 3900 feet. The aircraft was 50 feet AAE 1675 feet passed the runway threshold and used another 2125 feet before weight on wheels. Even so, with the derived ground run of 2900 feet the aircraft should have been stopped 1300 feet before the end of the 8000-foot runway.

The AFM factored landing field length of 6500 feet provided a safety margin in the event of a problem or long landing. The aircraft was slightly high over the threshold and used 1675 feet of the available 8000 feet before reaching 50 feet AAE. However, 6325 feet remained to land and bring the aircraft to a stop. If the aircraft's approach had positioned the aircraft at 50 feet above the threshold, with all other factors remaining the same, the aircraft would have used 6625 feet to stop. This value still exceeds the maximum value as defined by the AFM; however, the aircraft would have remained on the runway. Conversely, if the braking profile had matched that of previous flights, even with a threshold crossing height of 75 feet, the aircraft would have required 6700 feet from threshold to full stop. Although this is outside the margin specified in the AFM,it still leaves a margin of approximately 1300 feet to have completed the stop on the runway.

No fault was found with the brake system, so there may have been two instances of an intermittent fault: electrical, mechanical, or hydraulic. FDR data from the occurrence showed that the brakes were active and there was a low, fluctuating brake pressure, but there was a delay in the rise of brake pressure when compared to other landings. As this aircraft was not equipped to record pedal positions, it could not be determined from the FDR whether, when, or how much the pedals were being depressed. Also, the aircraft was not equipped to record wheel speed, so it is not possible to determine whether the wheels were spinning or stopped.

Several operational and human factors contributed to the occurrence. The pilots were aware of the wet runway conditions and the approximate landing distance required; therefore, they should have been aware of the requirement for a normal touchdown point on the 8000-foot runway, typically about 1000 feet from the threshold. Similarly, the flight crew would have been aware that a slower flap 45 approach would result in a shorter landing distance and reduce the risk of hydroplaning. Nevertheless, they conducted a flap 22 approach at a higher speed. The influences that led to this were the turn to intercept the localizer at close range, the need to begin the final descent to land, and the realization that it would be difficult to slow the aircraft enough for the flap 45 approach. Based on the FDR data, the PF had some difficulty capturing the localizer and the aircraft was high and fast on the approach. All of these factors led directly to the rushed and unstable approach. Additionally, the crew should have been aware of the need for a firm landing to reduce the risk of hydroplaning. Instead, the landing was long and smooth. On landing, the aircraft most likely entered a state of viscous or dynamic hydroplaning, with the anti-skid system modulating brake pressure to prevent wheel lockup. The aircraft remained in this state until the aircraft speed reached a point where hydroplaning ceased. At this point the anti-system allowed the brakes to come into full effect and effectively slow the aircraft.

The amount of time it took the PF to identify the brake problem and relay this information to the PNF was longer than expected for such an event. The PF's low experience on aircraft without thrust reversers, coupled with the wet runway, most likely delayed his recognition of the braking problem as he evaluated the situation and attempted to determine the cause of the lack of deceleration. Similarly, although the PNF may have recognized that the aircraft was not slowing as expected, he did not verbalize his concern to the PF in a timely manner.

Someone with access to the cockpit erased the CVR. Although the data was successfully retrieved, the erasure of the CVR is a serious contravention of the regulations and concerns the Board. CVR information is crucial to reconstructing what happened in the cockpit and, consequently, with the aircraft. It is the Board's expectation that the aviation community will assist our investigators by preserving all evidence, including that provided by the CVR. Interference with the CVR obstructs the work of the investigation and may prevent the Board from reporting publicly on causes and safety deficiencies.

Findings as to Causes and Contributing Factors

1. The approach to Runway 25 was high, fast, and not stabilized, resulting in the aircraft touching down almost halfway down the 8000-foot runway.

2. The aircraft landing was smooth; this most likely contributed to the aircraft hydroplaning on touchdown.

3. The anti-skid system most likely prevented the brake pressures from rising to normal values until 16 to 19 seconds after weight on wheels, resulting in little or no braking action immediately after landing.

4. The flight crew were slow to recognize and react to the lack of normal deceleration. This delayed the transfer of control to the captain and may have contributed to the runway overrun.

Other Findings

1. It could not be determined if an electrical, mechanical, or hydraulic brake problem existed at the time of the landing.

2. The flight crew did not take appropriate measures to preserve evidence related to the occurrence and, therefore, failed to meet the requirements of the FAR, CAR, and CTAISB regulations. Interference with the CVR obstructs TSB investigations and may prevent the Board from reporting publicly on causes and safety deficiencies.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 23 August 2005.

*Visit the Transportation Safety Board's Web site (**www.tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*

Appendix A: Landing Weight Estimation

		Assumptions			
Number of persons on board	31	Average weight of person (pounds)	180	Average weight of Baggage (pounds)	33
Operating Empty Weight (pounds)	26 014				
Total Pax weight (based on above assumptions)	5580				
Total Baggage weight (based on above assumptions)	1023				
Total Pax and Baggage weight (based on above assumptions)	6603				
Estimated Zero Fuel weight (pounds)	32 617	Max zero fuel weight for EMB-145LR from FAA TCDS T00011AT	39 462		
Calculated fuel use for flight (from RAPS) In pounds	3100				
Estimated Fuel remaining after flight (from pilot report) in pounds	8000				
Estimated total fuel weight on ramp	11 100				
Estimated Ramp Weight (pounds)	43 717	Max ramp weight for EMB-145LR From FAA TCDS T00011AT	48 721		
Estimated Landing Weight (pounds)	40 617	Max landing weight for EMB-145LR From FAA TCDS T00011AT	42 459		