Blown Away

NTSB said that nothing in the captain's experience or training had prepared him for the winds he encountered at Denver.

BY MARK LACAGNINA

Just as the captain relaxed rudder pressure while tracking the runway centerline for takeoff on a tumultuously windy day, the Boeing 737-500 was struck by a strong gust. Like a weathervane, the airplane turned into the crosswind and then ran off the side of the runway. Five of the 110 passengers and the captain were seriously injured; 38 passengers, two flight attendants and the first officer sustained minor injuries; 67 passengers and one flight attendant escaped injury. The airplane was substantially damaged during the excursion and postcrash fire.

In its final report on the accident, which occurred at Denver International Airport the

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afternoon of Dec. 20, 2008, the U.S. National Transportation Safety Board (NTSB) said that the probable cause was "the captain's cessation of rudder input, which was needed to maintain directional control of the airplane, about four seconds before the excursion, when the airplane encountered a strong and gusty crosswind that exceeded the captain's training and experience."

The report said that the following factors contributed to the accident: "an air traffic control system that did not require or facilitate the dissemination of key, available wind information to the air traffic controllers and pilots; and inadequate crosswind training in the airline industry due to deficient simulator wind gust modeling."

The 737 veered off Runway 34R, the inner runway of the parallel pair on the northwest side of the airport.

'Some Wind Out Here'

The airplane was being operated as Continental Airlines Flight 1404 to Houston. The pilots arrived at the airport about 1700 local time — one hour before the scheduled departure time.

The captain, 50, was hired by Continental in 1997 and served as a first officer in Douglas DC-9s, 737s, 757s and 767s before transitioning as a 737 captain about 14 months before the accident. He had about 13,100 flight hours, including 6,300 hours in 737s. Before joining Continental, he was a naval aviator.

The first officer, 34, was a flight instructor and regional airline pilot before being hired by Continental in March 2007. He held a 737 type rating and had about 8,000 flight hours, including 1,500 hours as a 737 first officer.

When the first officer, the pilot monitoring, requested clearance for pushback at 1804, he told the airport ramp controller that they had received automatic terminal information service (ATIS) Information Charlie, which reported surface winds from 280 degrees at 11 kt, 10 mi (16 km) visibility, a few clouds at 4,000 ft and a surface temperature of minus 6 degrees C (21 degrees F). A notice to airmen advised that patches of snow, ice and/or slush were on the ramps and taxiways, but the runways were bare and dry, the report said.

Denver International Airport has six runways, all at least 12,000 ft (3,658 m) long. Runways 25, 34L and 34R, all on the west side of the airport, were being used for departures. The airport ground controller instructed the crew to taxi to Runway 34R.

At 1814, the airport traffic controller told the crew to taxi into position and hold for departure on Runway 34R. After the crew completed the "Before Takeoff" checklist, the captain remarked, "Looks like you got some wind out here." The first officer replied, "Yeah." The captain said, "Oh, yeah. Look at those clouds moving."

Shortly thereafter, the controller advised that the winds were from 270 degrees at 27 kt and cleared the crew for takeoff. "Although this wind was significantly stronger than the wind reported by ATIS (280 degrees at 11 knots) 20 minutes earlier, the wind was still within Continental's crosswind guidelines of 33 knots," the report said.

Elusive Centerline

As the captain moved the thrust levers forward at 1817:38, he said, "All right. Left crosswind, twenty-seven knots." He later told investigators that when the airplane began to accelerate, he shifted his attention from the engine gauges to outside visual references and concentrated on tracking the runway centerline.

"The first officer stated that after the power was set, he shifted his attention to monitoring the airspeed so that he could make the standard

airspeed callouts, the first of which was 100 kt," the report said.

Recorded flight data indicated that as the airplane accelerated, the captain applied right rudder pedal inputs of increasing amplitude while holding the control wheel and control column in their neutral positions. The 737 was accelerating through about 55 kt at 1818:07, when it began to move left, away from the runway centerline. The captain responded two seconds later by moving the right rudder pedal almost all the way forward, displacing the rudder nearly to its maximum deflection of 26 degrees (Figure 1). "Almost simultaneous with the onset of this large rudder pedal input, the FDR [flight data recorder] began to record a left control wheel input," the report said.

The airplane began to head back toward the runway centerline. However, as it accelerated through about 85 kt at 1818:10, "the airplane's nose reversed direction and began moving back to the left at a rate of about one degree per second," the report said. "The leftward movement of the nose continued for about two seconds and was accompanied throughout its duration by another substantial right rudder pedal input."

This right rudder input slowed the left-turning motion momentarily, but the nose again began moving rapidly to the left at 1818:13, about the same time that the pilot relaxed pressure on the right rudder pedal, returning the pedal to its neutral position.

Shortly thereafter, the cockpit voice recorder (CVR) recorded an exclamation by the captain, and "the FDR recorded the beginning of a transition from left control wheel input (consistent with crosswind takeoff technique for a left crosswind) to right control wheel input (crossing the control wheel's neutral point at 1818:14)," the report said. "The FDR did not record any more substantial right rudder pedal inputs as the airplane continued to veer to the left."

As the airplane neared the edge of the runway, the captain tried unsuccessfully to use the nosewheel-steering tiller to regain directional control. The report noted that the tiller typically is used only during low-speed taxiing.

The captain later told investigators that he had "felt the rear end of the airplane slip out hard to the right and the wheels lose traction." He perceived that the airplane had encountered a slippery patch of runway, a strong gust of wind, or both.

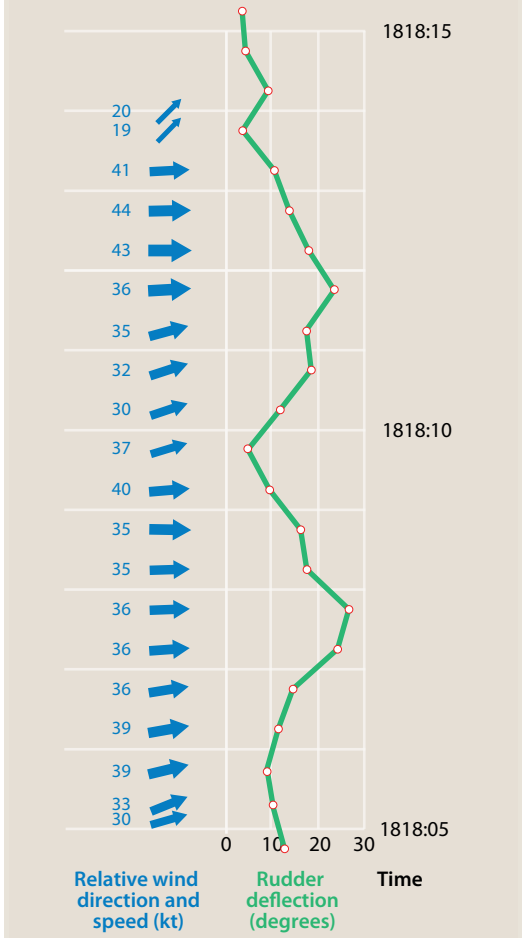
The first officer recalled that there was "a slight deviation left of centerline [at about 90 kt], but we seemed to be correcting back to the right." He said that the airplane then "abruptly swung approximately 30 degrees left with the tail to the right, and we were heading for the left side of the runway."

'Very Painful Bumps'

The CVR recorded an expletive voiced by the first officer just before the 737 ran off the left side of the runway at 1818:17. The captain called "reject" twice, announcing that he was rejecting the takeoff. "FDR data showed engine power reductions, as well as activation of the brakes," the report said. "Thrust reverser deployment began about three seconds after the airplane left the runway."

Groundspeed was about 110 kt when the airplane veered off the runway about 2,600 ft (792 m) from the approach threshold, on a magnetic heading of about 330 degrees. The pilots began reducing power, which also activated the autobrake, about three seconds later. The airplane crossed a taxiway and an airport service road, and came to a stop on a heading of about

Wind and Rudder Deflection



Source: U.S. National Transportation Safety Board, Susan Reed

Figure 1

The airplane had a rough ride on uneven terrain after leaving the runway at 110 kt.

315 degrees just north of an aircraft rescue and fire fighting (ARFF) station located between Runway 34R and Runway 34L. The FDR and CVR recordings ended at 1818:27.

"Postaccident interviews with passengers and crewmembers, as well as evidence from the crash site, indicated that as the airplane crossed the uneven terrain before coming to a stop, it became airborne, resulting in a jarring impact when it regained contact with the ground," the report said.

The captain told investigators that he was just "along for the ride" after the airplane veered off the runway. "Both pilots stated that there were a couple of 'very painful' bumps before the airplane came to a stop," the report said. "They indicated that they were somewhat dazed or 'knocked out' for one or two minutes after the airplane stopped and made no immediate attempts to get up or leave the cockpit."

Unable to communicate with the pilots, the flight attendants initiated an evacuation when they saw a fuel-fed fire erupt on the right side of the airplane. The flight attendants, assisted by two deadheading pilots, were able to evacuate all the passengers through the three left exits before the fire entered the cabin. Although injured, the captain and first officer exited without assistance. ARFF personnel arrived about five minutes after the evacuation was completed and extinguished the fire. The most serious injuries during the excursion involved back and/or spinal column damage.

Variable Winds

Denver International Airport is at an elevation of 5,431 ft in the foothills just east of the Front Range of the Rocky Mountains. Weather conditions on the day of the accident were influenced by a stationary front extending through Colorado. Analyses performed by the U.S. National Center for Atmospheric Research (NCAR) indicated that the airport was affected by significant mountain wave activity.

"The undulating motion of these waves as they moved eastward across [the airport] resulted in strong, very localized, intermittent gusts," the report said. The NCAR analyses indicated that a 45-kt gust was moving across the runway when the captain made the remark about cloud movement while awaiting takeoff clearance.

The flight crew had received wind information from different sources and locations on the huge airport. The ATIS wind information — 280 degrees at 11 kt — was derived from the automated surface observing system (ASOS) sensor located near the center of the airport, about 2.5 mi (4.0 km) southeast of the approach end of Runway 34R.

The wind information — 270 degrees at 27 kt — provided about 20 minutes later by the airport traffic controller who cleared the crew for takeoff was based on readings from a low level wind shear alert system (LLWAS) sensor located near the departure end of Runway 34R. Those readings, as well as readings from sensors

U.S. National Transportation Safety Board

associated with the ends of the other runways in use, were displayed on a monitor at the controller's station.

The flight crew did not, however, receive wind information from a closer source — an LLWAS sensor about 3,300 ft (1,006 m) from the approach end of Runway 34R. Readings from that sensor also were displayed on the controller's monitor and were designated as "AW," for "airport wind." When the crew was cleared for takeoff, the monitor showed the airport wind as from 280 degrees at 35 kt with gusts to 40 kt.

The controller did not provide and was not required to provide the "airport wind" information to the crew. "It was common practice for [airport] controllers to issue departure runway end winds to departing aircraft," the report said.

Based on the wind information that *was* provided, the crew's decision to depart on Runway 34R rather than requesting Runway 25 for takeoff was "reasonable," the report said. "Further, other airplanes departed on Runways 34L and 34R before the accident pilots' departure; the pilots of those departing airplanes did not report any crosswind-related issues or difficulties."

Investigators estimated that the 737 encountered direct crosswind components ranging from 29 kt to 45 kt during the takeoff roll. The peak gust of 45 kt occurred about the same time that the captain relaxed pressure on the right rudder pedal. The report said that the captain likely would have been able to maintain directional control if he had maintained or rapidly reapplied right rudder input. "Performance calculations indicated that the airplane's rudder was capable of producing enough aerodynamic force to offset the weathervaning tendency created by the winds the airplane encountered during the accident takeoff roll."

The report said that the "unusually large" rudder inputs that the captain made twice during the takeoff roll likely increased the difficulty he encountered in maintaining directional control. "To avoid overshooting the baseline heading after each large right rudder pedal input, the captain had to compensate by relaxing the right rudder pedal more than he would have had to for a smaller rudder pedal advancement," the report said. "Furthermore, because of slight delays in the effect each rudder pedal adjustment had on the airplane's rate of heading change, the captain had to anticipate the effect of each adjustment ahead of time. This task was very difficult for the captain because of the highly variable and unpredictable nature of the crosswind gusts."

The captain's full-right control wheel movement and use of the nosewheel steering tiller three seconds before the excursion "likely resulted from acute stress stemming from a sudden, unexpected threat, perceived lack of control and extreme time pressure," the report said, noting that these actions were ineffective and delayed the initiation of a rejected takeoff.

Insufficient Simulation

Postaccident flight simulator tests with pilots holding 737 type ratings showed that when they removed their feet from the rudder pedals while encountering a 35-kt crosswind at an airspeed of 90 kt, the "airplane" veered off the runway within five seconds. They were able to continue or reject the takeoff successfully if they resumed corrective rudder inputs within two seconds after releasing pedal pressure; but three seconds was too late. "Participants agreed that a three-second delay in reapplication of corrective rudder inputs resulted in a situation that would be unmanageable for a line pilot," the report said.

The participants also said that the flight simulator did not accurately reflect lateral forces or provide a good "seat of the pants" feel for wind gusts.

Investigators found that Continental's annual simulator recurrent training included takeoffs and landings with a 35-kt crosswind. "However, the company's 737-500 flight simulators were not programmed to simulate gust effects below about 50 feet above the ground and, therefore, were not capable of replicating the complex disturbances that pilots would experience during takeoffs and landings in gusty surface winds," the report said. "Further, takeoff data obtained from Continental indicated that the company's pilot rarely, if ever, encountered crosswind components greater than 30 knots during actual flight operations."

Based on the findings of the investigation, NTSB issued several recommendations to the U.S. Federal Aviation Administration, including more research on mountain waves and downslope winds; a requirement that controllers provide pilots with information on the maximum wind components they might encounter on takeoff or landing; a requirement that operators of air carrier, air taxi and fractional ownership aircraft incorporate "realistic, gusty crosswind profiles" in their simulator training; and a requirement that manufacturers of transport category airplanes develop type-specific crosswind limitations that account for wind gusts.

This article is based on NTSB Accident Report NTSB/AAR-10/04, "Runway Side Excursion During Attempted Takeoff in Strong and Gusty Crosswind Conditions; Continental Airlines Flight 1404; Boeing 737-500, N18611; Denver, Colorado; December 20, 2008." The full report is available at <ntsb.gov/Publictn/A-Acc1.htm>.