NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

June 19, 2009

OPERATIONS / HUMAN PERFORMANCE

GROUP CHAIRMEN'S FACTUAL REPORT

DCA09MA021

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A. ACCIDENT

Operator: Continental Airlines
Location: Denver International Airport, Denver, Colorado
Date: December 20, 2008
Time: 1818 Mountain Standard Time[1] (mst)
Airplane: Boeing B-737-500, N18611

B. OPERATIONS / HUMAN PERFORMANCE GROUP

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C. SUMMARY

On December 20, 2008, at 1818 mountain standard time, Continental Airlines (CAL) flight 1404, a Boeing 737-500 (registration N18611), equipped with CFM56-3B1 engines, departed the left side of runway 34R during takeoff from Denver International Airport (DEN). The scheduled, domestic passenger flight, operated under the provisions of Title 14 CFR Part 121, was enroute to George Bush Intercontinental Airport (IAH), Houston, Texas. There were 37 injuries among the passengers and crew, and no fatalities. The airplane was substantially damaged and experienced a post-crash fire. The weather observation in effect at the time of the accident was reported to be winds at 290 and 24 knots with gusts to 32 knots, visibility of 10 miles, a few clouds at 4000 feet and scattered clouds at 10,000 feet. The temperature was reported as -4 degrees Celsius.

[1] All times are Mountain Standard Time based on a 24-hour clock, unless otherwise noted. Actual time of accident is approximate.

D. DETAILS OF THE INVESTIGATION

On December 21, 2008, the Operations/Human Performance Group was formed and began the field phase of its investigation.

On December 22, 2008, the group interviewed the first officer. The group also interviewed a first officer who served as a flight crewmember on the accident airplane during its previous flight and who also rode as a passenger on the accident flight.

On December 23, 2008, the group interviewed a captain who served as a flight crewmember on the accident airplane during its previous flight and who also rode as a passenger during the accident flight. The group also interviewed a customer service agent and an operations coordinator who worked the flight. In addition, the group inventoried the accident flight crew's personal effects from the wreckage. Last, the group retrieved checklists and other documents from the cockpit of the accident airplane.

On December 24, 2008, the group interviewed the captain. The group also obtained some relevant manuals and documents from both CAL and the Federal Aviation Administration (FAA) and completed the on-scene phase of its investigation.

On January 26, 2009, the Operations/Human Performance Group reconvened at the CAL training center in Houston, Texas. Captain David C. Carbaugh of the Boeing Company joined the group at this time. The group toured CAL's pilot training facilities, reviewed B-737 training materials, policies and procedures, and interviewed the company's B-737 fleet/training manager.

On January 27, 2009, the group interviewed a B-737 flight instructor / aircrew program designee and conducted a variety of takeoff and rejected takeoff scenarios in a CAL B-737-500 level D flight simulator.

On January 28, 2009, the group interviewed the following individuals: the captain and first officer's most recent simulator instructors and line check airmen, two line pilots who recently flew with the accident captain and two line pilots who recently flew with the accident first officer.

On January 29, 2009, the group interviewed CAL's Director of Flight Safety and received a presentation about CAL's flight safety programs.

On January 30, 2009, the group obtained additional manuals and documents from CAL and concluded its activities in Houston.

1. Factual Information

1.1. History of Flight

Flight 1404 was scheduled to depart DEN for IAH at 1800. The flight crew arrived at the airport about 1700. The airplane had not yet arrived at the gate. The first officer bought coffee while the captain walked downstairs to get flight paperwork from an operations coordinator.

The pilots met at the gate after the airplane arrived. The captain did an external preflight inspection while the first officer performed preflight safety checks in the cockpit and did the "Receiving Aircraft" flow. After the captain returned to the cockpit, the two pilots discussed the upcoming flight, performed the receiving aircraft checklist, obtained a passenger count and weight and balance information, and entered the load information in the airplane's flight management computer.[2]

The flight crew instructed the cabin crew to close the airplane's doors. The first officer contacted ramp control and received a clearance to push back from the gate for a west taxi. The flight pushed back at 1801.[3] Ice and snow were visible on the ramp, so the captain started both engines and turned the engine and wing anti-ice systems on. The flight was cleared to taxi to 3W and the captain began to taxi the airplane. Approaching 3W, the first officer contacted ground control and received a clearance to taxi to runway 34R via taxiway F.

The flight crew heard ground control tell the flight in front of them that Automated Traffic Information System (ATIS) "Sierra" was current. The flight crew already had information Sierra, which reported winds at 270 degrees and 11 knots. They continued to taxi on taxiway F toward runway 34R. The captain did not notice any buffeting of the airplane from wind during the taxi.

As the airplane approached runway 34R, the flight crew performed the before takeoff checklist and contacted the tower. A Raytheon B-1900 was on the runway ahead of them, awaiting a takeoff clearance. After the B-1900 departed, the tower instructed flight 1404 to position and hold on the runway. The runway appeared to be clear of snow and ice, so the captain decided to de-select the engine and wing anti-ice systems but he left the engine igniters on. The captain positioned the airplane on the runway and the flight crew waited for two or three minutes. The runway lights and all of the airplane's lights were on and runway visibility was excellent.

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[2] Continental Airlines uses a computer based weight and balance system called ACCULOAD. It is an integral part of the Flight Operations Management System (FOMS) and is used to generate the Pilot Weight Manifest (PWM). ACCULOAD uses input from the dispatcher concerning MEL-CDL and weather restrictions, the information in FOMS (weather), as well as inputs from a qualified load planner (such as cargo, fuel, and customers) when computing weight and balance data. Weight adjustment codes can also be entered if necessary. ACCULOAD ensures that all performance and aircraft limitations are not exceeded. APWM will only be generated if the data is within the acceptable limits.

[3] The remaining material in this section is based on flight crew interviews conducted by the Operations/Human Performance Group.

The tower contacted the flight crew, informed them that winds were 270 degrees at 27 knots and cleared them for takeoff. The controller's wind report surprised the flight crew because it was higher than the wind reported in ATIS Sierra. The captain recalled saying something to the first officer like, "Roger, crosswind." The first officer recalled the captain saying, "Winds are 270 at 27. You ready?"

The captain was the flying pilot and he began a reduced-power takeoff. He first pushed the thrust levers up to achieve 40 percent N_1, then increased power to 70 percent N_1. He noticed a difference in the thrust being generated by the two engines, but the two engines matched as he increased N_1 to 90 percent. After verifying this, he pressed the TOGA button and called out, "check power." The first officer responded that thrust was set at 90.9% N_1. The captain applied a left control wheel correction, applied forward pressure to the yoke, and used variable right rudder to keep the airplane aligned with the runway centerline. He recalled that it felt at first like a "normal crosswind takeoff."

The captain recalled that as the airplane was getting up to speed it suddenly yawed to the left, as if hit by a "massive gust of wind," or as if the tires had hit a patch of ice and lost traction.[4] He recalled using full right rudder but seeing the airplane continue to veer left.[5] The first officer recalled that as airspeed was increasing from 87 to 90 knots he looked up and saw the airplane drifting left of the runway centerline. He thought the captain was correcting back to the right, but the airplane suddenly yawed 30 to 45 degrees to the left. It appeared to the first officer as if there was "zero directional control." He recalled feeling the rudder pedals with his feet and he believed the captain was applying full right rudder.

The captain recalled facing the edge lights on the left side of the runway. He believed the airplane was going to exit the left side of the runway and, as a last resort, he reached down with his left hand and grabbed the tiller for a second or two. He attempted to steer the airplane back onto the runway using the tiller, but this did not work so he put his left hand back on the yoke.[6]

The captain recalled using right control wheel to keep the wings level as the airplane departed the left side of the runway. He said that he did this because he thought the ground next to the runway sloped down and he feared that the aft end of the fuselage would slide down that incline and cause the airplane to "tumble on its side." After the airplane had completely exited the runway, the captain said "reject" and tried to deploy the thrust reversers. He recalled that he was unable to deploy the reversers because the ride was very rough.

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[4] The captain later recalled that the airplane was probably under 100 knots when this occurred, because he had not yet heard the first officer's 100-knot callout.

[5] The captain recalled no system warnings and no signs of any obvious system malfunctions. He recalled that he kept the right rudder "smashed to the ground" as the airplane veered toward the edge of the runway.

[6] He recalled that his right hand remained on the throttles and his foot continued to fully depress the right rudder pedal during this time. He said that he did not touch the brakes because he did not want to interfere with the auto-brakes, which were selected to the "rejected takeoff" setting.

The airplane was subjected to two violent impacts before it came to a stop. It was totally dark inside the cockpit. Neither the captain nor the first officer recalled hearing any engine sounds. Both were stunned and in pain and they felt incapable of doing anything for one or two minutes. They did not order an evacuation or perform the evacuation checklist.

After recovering from the initial shock of the crash, the first officer opened a cockpit window to his right and threw out an escape rope, but he saw fire along the right side of the airplane and decided not to exit that way. He got out of his seat so he could exit through the cabin instead. As the first officer stood up, a deadheading crewmember knocked on the cockpit door and the first officer opened it. About this time, the captain was trying to get out of his seat as well, but a dislodged flight crew bag was blocking his path. The first officer moved the bag and he and the deadheading crewmember helped the captain out of the cockpit. The deadheading crewmember told the first officer that all of the passengers had been evacuated and then the captain, first officer and deadheading crewmember exited the airplane via the L1 slide.

1.5. Personnel Information

The flight crew consisted of two pilots: a captain and a first officer. The day of the accident was the fourth day of a four-day pairing for the two pilots. They had been paired with each other on one or two prior trips, most recently about a month before the accident and they reported a history of positive professional interactions.

1.5.1. The Captain, David Butler

The captain, age 50, resided near Houston, Texas.

The captain began his aviation career in 1979 at the U.S. Navy's Officer Candidate School. He flew the Douglas A-3D Skywarrior from 1983 to 1986 and then transitioned to the Grumman EA-6B Prowler. He flew the Prowler for the next 8 years. During his time in the Navy, the captain completed 5 deployments, spent 3.5 years on an aircraft carrier, made about 600 carrier landings (200 at night), and flew 22 combat missions. He had about 4,500 hours of flight experience when he left the military in 1993.

CAL hired the captain on November 5, 1997. He initially served as a DC-9 first officer. A year and a half later he transitioned to the position of B-737 first officer. Five years later he transitioned to the position of B-757/767 first officer. Two years after that he transitioned to the position of B-737 captain. He had been a B-737 captain for about 14 months at the time of the accident.

1.5.1.1. The Captain's Flight Experience

The captain's flight experience is summarized in Table 1.[7]

[7] The captain's flight experience at the time of the accident was estimated using company records and information provided by the captain. These figures include the accident flight.

Table 1.
The captain's flight experience.

Flight Time	Flight Hours
Total	13,100
B-737	6,300
B-737 PIC	1,015
Last 12 months	915
Last 90 days	216
Last 30 days	81
Last 7 days	7
Last 24 hours	7

1.5.1.2. The Captain's Pilot Certification History

At the time of the accident, the captain held an airline transport pilot certificate (ATP) with an airplane multi-engine land rating and Boeing B-737, B-757 and B-767 type ratings. His certificate bore a limitation stating that he could perform circling approaches in the B-737, B-757, and B-767 in visual meteorological conditions (VMC) only. A chronology of the captain's FAA certificates and ratings is shown in table 2. FAA certification records revealed no history of failures or re-tests for FAA airman certificates and ratings. A search of FAA records revealed no FAA enforcement actions, incidents or previous accidents.

Table 2.
Chronology of the captain's acquisition of FAA pilot certificates and ratings.

Certificate / Rating	Original Issue Date
Commercial Pilot – Airplane Multiengine Land[8]	June 7, 1991
Commercial Pilot – Instrument Airplane[9]	June 7, 1991
Airline Transport Pilot – Airplane Multiengine Land	July 11, 1993
Commercial Pilot – Airplane Single Engine Land	August 9, 1996
B-737 Type Rating	November 13, 1999
B-757/767 Type Rating	July 13, 2005

1.5.1.3 The Captain's Recent Training and Proficiency Checks

The captain's most recent CAL training and proficiency checks are listed in table 3. All of these checks were passed in a satisfactory manner. Company records revealed no history of difficulties with training or performance.

Table 3.
Chronology of the captain's B-737 training and checks.

Type of training or Check	Completion Date
Initial type rating B-737	November 13, 1999
Last line check	April 14, 2008
Last B-737 recurrent ground training	October 9, 2008
Last B-737 proficiency check	October 11, 2008

[8] Limited to center line thrust. Certificate issued based on military competence.
[9] Certificate issued based on military competence.

1.5.1.4. The Captain's 72-Hour History

The captain's activities in the 72 hours before the accident were reconstructed based on company records and the recollections of the captain, first officer and others.

The captain's recent work schedule is shown in Table 4.[10]

Table 4.
The captain's recent work schedule.*****

Date	Prior Rest	Duty Start	Duty End	Duty Period	Legs Flown	Daily Flight Time
12/17/2008	Days	0630 IAH	1022 SFO	05:52	1	4:28
12/18/2008	23:55	1017 SFO	2147 PHL	08:30	2	6:34
12/19/2008	17:13	1500 PHL	2154 DEN	08:54	2	6:19
12/20/2008	19:36	1730 DEN	1818**	00:48**		

*Note: Times shown are local (IAH = CST, SFO = PST, PHL = EST, DEN = MST).
**Note: Duty end and cumulative duty time on 12/20/2008 is based on the time of the accident.

On Wednesday, December 17, the captain operated a flight from IAH to San Francisco International Airport (SFO) with the first officer and went off duty at 1022. He went to his hotel, took a nap, ate lunch, rested in his hotel room and ate dinner. He went to bed between 2000 and 2100.

On Thursday, December 18, the captain woke about 0600, had breakfast at his hotel and took a shuttle to the airport with the first officer. They operated two uneventful flights: SFO to IAH and IAH to Philadelphia International Airport (PHL). He arrived at his hotel in Philadelphia about 2200 and went to bed between 2230 and 2300.

On Friday, December 19, the captain woke between 0800 and 0900. He felt "well rested." He took a taxi to a shopping mall, had lunch, ran some errands and walked back to his hotel. He and the first officer reported for duty in the afternoon. They operated uneventful flights from PHL to IAH and from IAH to DEN. He went off duty about 2154 and arrived at his hotel in Denver about 2300. He went to bed by 2330.

On Saturday, December 20, the captain woke about 0800. He felt "great." He ate breakfast at his hotel. He left the hotel about 1400, had lunch with friends and returned to the hotel. He left the hotel about 1630 and traveled to DEN in a shuttle with the first officer. They arrived at 1700, about an hour before their scheduled departure.

The captain recalled feeling "upbeat" and rested. The first officer also stated that the captain was in a good mood and appeared rested. A CAL operations coordinator who interacted with the captain before the flight said the captain seemed "normal." A CAL gate agent who helped board the flight's passengers interacted with the flight crew and said the captain seemed alert and friendly.

[10] Information drawn from company records.

The captain told investigators he needed 8 hours of sleep per night to feel rested. He described himself as an "afternoon person" and he said he preferred working in the afternoon or evening to working in the morning. His self-reported sleep history in the three days before the accident is summarized in table 5.

Table 5.
The captain's self-reported sleep history, February 17-20, 2008.*****

Date	**Begin**	**End**	**Reported Time in Bed**	**Subjective Sleep Quality**
February 17 – 18	2200/2300	0800	9 to 10 hours	Not reported
February 18 – 19	2130/2200	0700/0800	9 to 11.5 hours	"Well rested"
February 19 – 20	0030	0900	8.5 hours	"Great"

*Note: Sleep start and end times expressed in Central Standard Time, the captain's home time zone.

1.5.2. The First Officer, Chad Gordon Levang

The first officer, age 34, resided near Houston, Texas.

The first officer began his aviation career at the University of North Dakota. After graduating in 1998, he remained at the university as a flight instructor for about a year until he was hired in 1999 by Horizon Air. At Horizon, he was based in Portland, Oregon. He flew the De Havilland Dash 8-200 and –400.

The first officer was hired by CAL in March 2007. He had been a B-737 first officer at CAL since that time.

1.5.2.1. The First Officer's Flight Experience

The first officer's flight experience is summarized in table 6.[11]

Table 6.
The first officer's flight experience at the time of the accident.

Flight Time	**Flight Hours**
Total	7,500
B-737	1,500
B-737 SIC	1,500
Last 12 months	918
Last 30 days	34
Last 7 days	7
Last 24 hours	7

1.5.2.2. The First Officer's Pilot Certification

The first officer held an ATP certificate with DeHavilland DHC-8 and Boeing B-737 type ratings. His ATP certificate bore a limitation stating that he could only perform circling

[11] The first officer's flight experience was estimated using company records and information provided by the first officer. These totals include the accident flight.

approaches in VMC. The first officer also held a flight instructor certificate with airplane single engine, airplane multi-engine, and instrument airplane ratings. A chronology of his completion of FAA certificates and ratings is shown in table 7. FAA records revealed no history of any failures or re-tests for FAA airman certificates and ratings, and no evidence of enforcement actions, incidents, or previous accidents.

Table 7.
Chronology of the first officer's acquisition of FAA pilot certificates and ratings.

Type of Certificate or Rating	Original Issue Date
Private Pilot – Airplane Single Engine Land	May 24, 1995
Commercial Pilot – Airplane Single Engine Land	May 23, 1997
Commercial Pilot – Airplane Multi Engine Land	May 23, 1997
Instrument Airplane	May 23, 1997
Flight Instructor – Airplane Single Engine	March 24, 1998
Flight Instructor – Instrument Airplane	May 26, 1998
Flight Instructor – Airplane Multiengine	May 5, 2000
Airline Transport Pilot – Airplane Multiengine Land	February 3, 2001
DHC-8 Type Rating	February 3, 2005
B-737 Type Rating	May 5, 2007

1.5.2.3. The First Officer's Training and Proficiency Checks

Table 8 lists the dates of the first officer's most recent CAL training and proficiency checks. All of these checks were passed in a satisfactory manner. A review of CAL records revealed no history of difficulties with training or performance.

Table 8.
Chronology of the first officer's most recent B-737 training and checks.

Type of training or Check	Completion Date
Initial B-737	May 4, 2007
B-737 recurrent ground training	December 1, 2008
B-737 proficiency check	December 2, 2008
Line check	September 29, 2008

1.5.2.4. The First Officer's 72-Hour History

The first officer's activities in the 72 hours before the accident were reconstructed using company records and information provided by the first officer, the captain and others. His recent work schedule is shown in Table 9.[12]

[12] Information drawn from company records.

Table 9.
The first officer's recent work schedule.*

Date	Prior Rest	Duty Start	Duty End	Duty Period	Sectors Flown	Flight Time
12/17/2008	Multiple days	0630 IAH	1022 SFO	05:52	1	4:28
12/18/2008	23:55	1017 SFO	2147 PHL	08:30	2	6:34
12/19/2008	17:13	1500 PHL	2154 DEN	08:54	2	6:19
12/20/2008	19:36	1730 DEN	1818**	00:48**		

*Note: Times shown are local (IAH = CST, SFO = PST, PHL = EST, DEN = MST).
**Note: Duty end and cumulative duty time on 12/20/2008 is based on the time of the accident.

On Wednesday, December 17, the first officer operated a flight from IAH to SFO. He went off duty at 1022 and checked into his hotel in San Francisco. He watched television and took a nap, sleeping from about 1330 until 1600 or 1700. He ate dinner at the hotel between 2000 and 2100 and went to bed about midnight. He had a mild sore throat.

On Thursday, December 18, the first officer woke about 0800. His quality of sleep was "not great" because he had napped the previous afternoon. He traveled to SFO and went on duty at 1014. He operated two flights with the accident captain, SFO to IAH and IAH to PHL. He went off duty at 2147 and went to his hotel in Philadelphia. He spent the evening in his room and went to sleep about midnight.

On Friday, December 19, the first officer woke between 0800 and 0830. His quality of sleep was "good." He felt refreshed. The captain invited him for breakfast, but the first officer had not brought warm clothes and he had a mild illness, so he declined, eating breakfast in the hotel instead. At 1415, the first officer traveled to PHL with the captain and they went on duty at 1500. The airplane was late, so he picked up food and coffee to bring aboard. They departed at 1554, operating two legs: PHL to IAH and IAH to DEN. He went off duty in Denver at 2154, went directly to his hotel, engaged in routine activities and went to bed between 0100 and 0130.

On Saturday, December 20, the first officer woke between 1000 and 1100. His quality of sleep was "pretty good." He left the hotel about 1400, had lunch at a restaurant, returned to his hotel and took a shuttle to DEN with the captain. They arrived at the airport at 1700, about an hour before their scheduled departure. The airplane was not at the gate, so the first officer got coffee while the captain retrieved flight paperwork.

The first officer recalled that his throat felt a little sore before the accident, but that he did not feel ill or think his performance capacity was diminished.[13] The captain recalled that the first officer seemed "upbeat". A gate agent who boarded the flight's passengers stated that she did not notice anything unusual about him.

[13] He recalled that he could swallow, but his throat was "scratchy."

The first officer said that he liked 7 to 9 hours of sleep per night and that he was more of an evening person than a morning person. His self-reported sleep history in the days before the accident is summarized in table 10.

Table 10.
The first officer's self-reported sleep history, February 17-20, 2008.

Date	Begin	End	Reported Time in Bed	Subjective Sleep Quality
February 17 – 18	0200	1000	8 hours	"Not great"
February 18 – 19	2300	0700 / 0730	8 to 8.5 hours	"Good"
February 19 – 20	0200 / 0230	1100 / 1200	8.5 to 10 hours	"Pretty good"

*Note: Sleep start and end times expressed in Central Standard Time, the first officer's home time zone.

1.6. Airplane Information

1.6.1. Weight and Balance, Configuration, and Speeds

The airplane's weight and balance information, configuration and speeds were determined using the manufacturer's airplane flight manual and Accuload – Pilot Weight Manifest. This information is summarized in tables 11 and 12.

Table 11.
Airplane weight and balance information.

Parameter	Weight in Pounds
Basic Operating Weight	73,000
Passengers	21,450
Baggage/Cargo	2,850
Zero Fuel Weight	97,300
Maximum Zero Fuel Weight	103,000
Fuel (actual fuel minus taxi fuel)	19,600
Gross Takeoff Weight	116,900
Maximum Gross Takeoff Weight	120,100

Table 12.
Airplane center of gravity, configuration and speeds.

Parameter	Value
Center of Gravity (CG)	21.5 percent mean aerodynamic chord (MAC)
Takeoff CG Limits	5 to 25 percent MAC
Takeoff Flap Setting	5[14]
Takeoff Stabilizer Trim Setting	3¾ ANU
Takeoff Speeds	V_1=137 knots, V_R=140 knots, V_2=146 knots

[14] There are nine flap positions: 0, 1, 2, 5, 10, 15, 25, 30, and 40.

1.6.2. CAL Standard Operating Procedures

1.6.2.1. Normal Takeoff

CAL's Boeing B-737 Flight Manual[15] normal takeoff procedure included the following guidance with respect to setting takeoff thrust.

> A rolling takeoff is recommended. As the aircraft is aligned with the runway, the Pilot Flying will smoothly advance both throttles, ensuring symmetrical engine acceleration, to approximately 40% N_1 and allow the engines to stabilize. The throttle position will be about ¾" forward of idle. Unrestricted advancement of the throttles can cause asymmetric thrust with directional control problems, especially on slippery runways.
>
> Caution: The nose wheel steering (tiller) should not be used above normal taxi speeds (20 knots).
>
> After the engines are stabilized, the PF will manually advance the throttles toward the takeoff power setting, and engage TOGA when satisfied that engine acceleration is normal. Normally TOGA will be engaged as the throttles reach the vertical (70% N_1) position. As the throttles reach the end of their forward movement, the PF calls "CHECK POWER," and the PM ensures that the throttles stabilize at takeoff N_1 (referencing the TAKEOFF PAGE of the FMC) and replies "POWER SET ____%."
>
> Note: Both F/D switches must be on to engage the F/D Takeoff mode (TOGA). The F/D switches are not required to engage autothrottle only.
>
> A/T annunciates N_1 and AFDS annunciates TOGA. The thrust levers drive forward and flight director bars command 10 degrees nose down. The F/D does not provide runway steering guidance or rotation commands. At approximately 60 knots, the F/D will command 15 degrees nose up.

CAL'S Boeing B-737 Flight Manual[16] normal takeoff procedure included the following guidance with respect to the takeoff roll.

> Keep the airplane on the centerline with rudder pedal steering and rudder. The rudder becomes effective between 40 and 60 knots. Use of the nose wheel steering tiller during takeoff is not recommended.

The flight manual stated that the captain was to retain control of the throttles from the time takeoff power was set until airspeed reached V_1 and the captain should remain prepared to perform a rejected takeoff if one was required. The manual stated that the pilot monitoring was to monitor essential instruments during the takeoff, including engine, oil pressure and autothrottle mode indications. The pilot monitoring was also responsible for crosschecking the airspeed with the standby airspeed indicator and for calling out certain airspeeds, including 100 knots, V1, and rotation speed.

The flight manual's normal procedure for crosswind takeoff[17] included the following additional information:

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[15] Revision 06/01/08 #46, Section 3, Normals, Takeoff Procedure, Setting Takeoff Thrust, p.118.
[16] Revision 08/01/06 #44, Section 3, Normals, Takeoff Procedure, Takeoff Roll, p.119.
[17] Revisions 11/01/05 #43, Section 3, Normals, Crosswind Takeoff, p.120.

Refer to Recommended Takeoff Crosswind Component Guidelines, Section 1, Limitations. The crosswind takeoff characteristics are typical of most swept-wing transports. The upwind wing will tend to rise as the takeoff roll begins. This may be corrected by using aileron as required or by pre-setting a fixed amount of aileron into the wind prior to takeoff roll. Maintain a slight forward pressure on the control yoke until approaching rotation speed. In either case, large control wheel oscillations and inputs should be avoided.

Another indication of a crosswind condition is the tendency of the aircraft to weather vane into the wind, requiring rudder application for directional control. As speed increases, the aileron deflection requirement will decrease. Continue to maintain directional control with smooth rudder application. This will result in a cross control condition that must be maintained through liftoff. During rotation, hold the control wheel in a displaced position as required to keep the wings level. When airborne, aileron and rudder cross control should be slowly and smoothly relaxed.

For takeoff in gusty or strong crosswind conditions, consider using a higher thrust setting (up to maximum if appropriate) consistent with takeoff weight, weather conditions, runway length, and aircraft performance. When the prevailing wind is at or near 90° to the runway, the possibility of wind shifts resulting in gusty tailwind components during rotation or liftoff increases. The use of a higher thrust setting reduces the required runway length and minimizes the airplane exposure to gusty conditions during rotation, liftoff, and initial climb.

Avoid rotation during a gust. If a gust is experienced near V_R, as indicated by stagnant airspeed or rapid airspeed acceleration, momentarily delay rotation. This slight delay allows the airplane additional time to accelerate through the gust and the resulting additional airspeed improves the tail clearance margin. Do not rotate early or use a higher than normal rotation rate in an attempt to clear the ground and reduce the gust effect because this reduces tail clearance margins. Limit control wheel input to that required to keep the wings level. Use of excessive control wheel may cause spoilers to rise which has the effect of reducing tail clearance. All of these factors provide maximum energy to accelerate through gusts while maintaining tail clearance margins at liftoff. The airplane is in a sideslip with crossed controls at this point. A slow, smooth recovery from this sideslip is accomplished after liftoff by slowly neutralizing the control wheel and rudder pedals.

1.6.2.2. Takeoff in Windshear Conditions

CAL'S Boeing B-737 Flight Manual[18] adverse weather procedure for takeoff in windshear conditions included the following information.

If, after careful consideration, the decision to takeoff is made:

1. Select the longest suitable runway that avoids suspected areas of windshear. The choice of a suitable runway involves consideration of exposure to obstacles after liftoff and crosswind and tailwind limitations.
2. Use a takeoff flap setting of 5 unless limited by obstacle clearance and/or climb gradient. This setting provides the best performance for countering windshear.
3. Maximum rated takeoff thrust should be used. (Reduced Thrust takeoff is prohibited.)
4. Use flight director display.
5. Use autothrottle.
6. Use increased airspeed at rotation when available. To compute the increased rotation airspeed:

[18] Revision 11/01/07 #45, Section 3, Normals, Supplementary, Adverse Weather, p.335.

- Determine the V_1, V_R, and V_2 speeds for the actual aircraft gross weight and flap setting. Set reference speeds to these values in the normal manner.

  Caution: Runway Analysis is not provided when scheduled for improved takeoff. If increased performance is desired, use the following procedures:

- Contact load planning and request a "Windshear Takeoff" ACCULOAD.

- Use the takeoff speeds on the new ACCULOAD.

- From the automated runway analysis, pre-departure papers determine the runway limit weight for the selected runway. Then determine V_R for that weight (field length limit V_R).

- If the field length limit V_R is greater than the actual gross weight V_R, (almost always the case) use the higher V_R (up to 20 knots in excess of actual gross weight V_R) for takeoff.

  Note: Reference speeds should not be reset to the higher airspeeds.

7. Rotate to normal initial climb attitude at the increased V_R and maintain this attitude. This technique produces a higher initial climb speed which slowly bleeds off to the normal climb speed.
8. Once the takeoff is initiated, the flight crew should be alert for airspeed fluctuations. If significant airspeed variations occur below V_1 the takeoff should be rejected if sufficient runway remains.

   Caution: Accelerate / Stop distances are computed assuming a normal acceleration to V_1. Airspeed fluctuations may cause the aircraft to achieve V_1 at a point farther down the runway than anticipated. Therefore, the aircraft may not be able to stop on the runway.

9. When windshear is encountered:

- At or above the actual gross weight V_R
  - o Do not attempt to accelerate to the increased VR, but rotate without hesitation
- At or near the actual gross weight VR and airspeed suddenly decreases:
  - o There may not be sufficient runway left to accelerate back to normal VR. If there is insufficient runway left to stop, initiate a normal rotation at least 2,000' before the end of the runway, even if airspeed is low. Higher than normal attitudes may be required to lift off in the remaining runway. Aft body contact may occur
- Throttles may be advanced to the mechanical stops
- If increased airspeed was not used prior to liftoff, accelerating to higher than normal airspeed after liftoff is not recommended. Reducing pitch attitude at low altitude to accelerate might produce a hazard if windshear is encountered.

1.6.2.3. Rejected Takeoff

CAL'S Boeing B-737 Flight Manual[19] Non-normal Procedures included the following information regarding the decision to perform a rejected takeoff.

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[19] Revision 06/14/04 #42, Section 2.0, Non-Normals, Unannunciated, Rejected Takeoff, p.19.

A Rejected Takeoff (RTO) is a maneuver performed during the takeoff roll to expeditiously stop the aircraft on the runway.

At low speeds (up to approximately 100 knots), the energy level is low. Therefore, the aircraft should be stopped if an event occurs that would be considered undesirable for continued takeoff.

As the airspeed approaches V_1, the effort required to stop the aircraft can approach the aircraft's maximum stopping capability. After 100 knots and before V_1, the takeoff should be rejected only for engine failure, a confirmed unsafe configuration, or other conditions that severely affect the safety of flight. V_1 is the maximum speed at which the RTO should be initiated. Therefore, the decision to stop must be made prior to V_1.

Historically, rejecting a takeoff near V_1 has often resulted in the aircraft coming to a stop beyond the end of the runway. Common causes include initiating the RTO at or after $V_{\underline{1}}$ and failure to use proper procedures (maximum stopping capability).

Do not reject the takeoff after V_1 unless the Captain judges the aircraft incapable of flight. Even if excess runway remains after V_1, there is no assurance that the brakes and/or reversers will have the capacity to stop the aircraft prior to the end of the runway.

The manual's non-normal procedure for the rejected takeoff maneuver[20] included the following additional information:

The Captain is responsible for performing all rejected takeoffs. When the First Officer is making the takeoff, he/she will place both hands on the yoke after initially setting takeoff power and the Captain has assumed control of the throttles. The Captain will be prepared to perform the rejected takeoff maneuver, if required. If a rejected takeoff is required or called for by the Captain prior to the First Officer removing his/her hand from the thrust levers, the First Officer will retard the thrust levers to idle and assist the Captain in the rejected takeoff maneuver.

During the takeoff roll, the Pilot Monitoring will monitor all instruments and indicators. Below 100 knots, any abnormality should be called out. Above 100 knots the only callout normally made is "POWER LOSS." This callout is made when any crewmember observes a confirmed engine power loss. Above 100 knots, other conditions that severely affect the safety of flight should also be considered and, if appropriate, a callout made. If a non-normal is verbalized during the takeoff roll, the Captain will evaluate the situation and make the go / no-go decision. If the Captain elects to continue he/she should clearly and loudly call out "CONTINUE." In this case, the Pilot Flying will continue the takeoff using normal procedures.

If the Captain initiates a reject, he/she will clearly and loudly announce, "REJECT." As the aircraft decelerates, the First Officer should ensure that proper aileron control input is maintained. Additionally, during a First Officer takeoff and after the Captain assumes control of the thrust levers, the First Officer will relinquish control of the aircraft to the Captain as soon as "REJECT" is heard.

Transition to manual braking should be verbalized with the call "MANUAL BRAKES."

As soon as conditions permit, the First Officer should notify ATC of the rejected takeoff, and will make a "REMAIN SEATED", "REMAIN SEATED" announcement to the cabin.

[20] Revision 06/14/04 #42, Section 2.0, Non-Normals, Unannunciated, Rejected Takeoff, p.19.

During any rejected takeoff, the Captain should:

- Close the throttles.
- Disconnect autothrottle.
- Apply maximum reverse thrust.
- Ensure that the speedbrakes automatically deploy.
- Use RTO autobrakes (if available).

In the event the speedbrakes do not deploy, the First Officer will call "SPEEDBRAKES" and the Captain will manually deploy the speedbrakes. Use RTO brakes or manual braking as required. On a wet or slippery runway, or takeoff at or near maximum runway limit weight, an aborted takeoff at or near V_1 will require MAXIMUM use of all deceleration devices until reaching a full stop.

Whenever a decision is made to reject a takeoff, the following limiting criteria must be considered: weather conditions, runway length and conditions, aircraft weight and takeoff performance limits, and MEL/CDL items affecting aircraft performance.

REJECTED TAKEOFF CONSIDERATIONS	
Below 100 Knots	**Above 100 Knots**
• Engine Failure / Fire • Unsafe / Unable to Fly • Cabin Smoke / Fire • System Failure • Unusual Noise or Vibration • Tire Failure • Abnormal Acceleration • Takeoff Configuration Warning • Windshear Warning	• Engine Failure • Unsafe / Unable to Fly

Once the aircraft has slowed to a safe speed, it is up to the Captain:

- When and where to exit the active runway.
- When and if to set the parking brake.
- To make a decision whether to evacuate the aircraft, return to the gate, or return for takeoff. Additional information may be required.

In order to determine the best course of action, the following factors should be considered:

- What was the reason for the rejected takeoff - a mechanical problem, an ATC call, etc?
- What is the overall status of the aircraft - is it able to safely taxi?
- What is the status of the F/As, passengers and emergency exits - are they seated and are all doors closed?
- Is emergency equipment required, and can they access the aircraft better on the runway or taxiway?
- Is it prudent to set the parking brake while evaluating the situation if the brakes are very hot?
- What are the effects of hot brakes and tires as it pertains to brake fires, blown fuse plugs, and hazards to ground personnel?
- Is there any other relevant information pertinent to assessing the situation?

If there is doubt as to the most appropriate course of action, the aircraft should be stopped straight ahead on the runway until the situation can be resolved. After the aircraft comes to a complete stop, the Captain will call for the REJECTED TAKEOFF CHECKLIST.

REJECTED TAKEOFF DUTIES	
During takeoff, the crewmember recognizing the malfunction will call it out clearly and precisely.	
CAPTAIN	**FIRST OFFICER**
Calls "REJECT." Simultaneously brings both thrust levers to idle and disengages the autothrottles. Confirms RTO braking or initiates maximum manual braking. Initiates maximum reverse thrust consistent with runway and aircraft conditions. Raise speedbrake lever if not already. Announces "MANUAL BRAKES" when autobrakes disengage. Calls for "REJECTED TAKEOFF CHECKLIST."	Confirms the following actions: • Both thrust levers idle • Autothrottles disengaged • RTO or manual brakes • Reverse thrust • (Calls if other than both reversers operating normally, such as "LEFT REVERSER ONLY.") • Speedbrake lever full up. (If speedbrake lever is not up calls "SPEEDBRAKES.") Call "80 KNOTS." Calls "MANUAL BRAKES" if not called by the Captain. Notify Tower/Ground of reject and status. Notify cabin to "REMAIN SEATED, REMAIN SEATED." Accomplish REJECTED TAKEOFF checklist.

CAL'S Boeing B-737 Flight Manual non-normal procedure for a rejected takeoff[21] included the following additional information:

Tower / Ground .... NOTIFY

First Officer should advise ATC that the takeoff has been rejected, state aircraft location, and request assistance if applicable.

Passenger PA .... "REMAIN SEATED, REMAIN SEATED"

First Officer should make announcement.

Parking Brake .... AS REQUIRED

IF Engine Failure, Engine Fire, or APU Fire:

Engine Start Lever (Affected Engine) ....CUTOFF

[21] Revision 11/01/05 #43, Section 2.0, Non-Normals, Unannunciated, Rejected Takeoff, p.23.

Position start lever to cutoff on affected engine. This will close fuel valves to stabilize engine and reduce possible fuel leakage from damaged fuel lines.

Fire Handle (If Illuminated)...................................... PULL & ROTATE LEFT & RIGHT

Pull, rotate and hold to the stop for one second. Reverse direction to discharge remaining engine fire bottle.

IF Evacuation Is NOT Required:

- Identify the malfunction.
- Accomplish the required checklist(s) at an appropriate time and location. If actions required crew to address engine failure, engine fire, or APU fire, no additional checklist is to be accomplished.
- If the aircraft has been brought to a complete stop, do not resume taxiing until the Flight Attendants have verified all passengers are seated and all doors / exits are closed. Make a brief PA reassuring customers and flight attendants that the situation is under control and inform them of your intentions.

Caution: If tire damage is suspected, do not retract flaps.

- Note: If returning to the gate, accomplish the AFTER LANDING checklist. Or if returning to runway for takeoff, accomplish the BEFORE TAKEOFF checklist and confirm Autobrake system is reset to RTO.

Brake Cooling..DETERMINE

Refer to the appropriate aircraft RTO BRAKE COOLING CHART.

IF Evacuation IS Required:

Accomplish EMERGENCY EVACUATION Checklist.

The manual's normal procedures included the following additional information regarding a flight attendant briefing with respect to rejected takeoff and evacuation coordination: [22]

As per SOP, in the event of a rejected takeoff or a non-normal landing, you can expect the flight deck will give the PA command "REMAIN SEATED, REMAIN SEATED" as soon as possible. Keep the passengers seated and calm while evaluating your assigned exit door window. As soon as the flight crew is able, they will make an appropriate announcement, explaining what the course of action will be. If you observe something inside or outside the aircraft that is of obvious danger, relay the information to the flight deck. If contact with the flight deck is not possible, signal with 4 chimes and if absolutely necessary, initiate an evacuation.

The manual's normal procedures included the following additional information, in part, with respect to operational precautions and takeoff considerations: [23]

[22] Revision 06/01/08 #46, Section 3, Normals, General, Crew Briefings, Flight Attendant Briefing, p.10.
[23] Revision 08/01/06 #44, Section 3, Normals, Supplemental, Adverse Weather, Operational Precautions, p.334.

If operating from an airport with Terminal Doppler Weather Radar:

- A Microburst Alert or Windshear Alert will be issued by the tower in conjunction with a clearance to a specific runway. If the clearance does not contain an alert, the flight crew may assume that no alert exists at the present time.
- If a Windshear Alert accompanied by a reported gain of airspeed is issued, the crew may take off, but be alert for sudden airspeed increase. If airborne, the pilot should adjust pitch attitude smoothly to maintain desired airspeed, but should not chase large rapid airspeed fluctuations.
- If a Windshear Alert accompanied by a reported loss of airspeed, or a Microburst Alert is received, a takeoff should not be attempted. If either alert is received during takeoff prior to 100 knots, the takeoff should be rejected. If either alert is received after 100 knots, the takeoff may be rejected or continued at Captain's discretion after considering runway available, gross weight, and related meteorological conditions.

1.6.2.4. Autobrake System

CAL'S Boeing B-737 Flight Manual[24] section on the autobrake system and the rejected takeoff (RTO) mode included the following information.

> The autobrake system uses hydraulic system B pressure to provide maximum deceleration for rejected takeoff and automatic braking at pre-selected deceleration rates immediately after touchdown. The system operates only when the normal brake system is functioning. Anti-skid system protection is provided during autobrake operation.
>
> The Rejected Takeoff (RTO) mode can be selected only when on the ground. Upon selection, the AUTO BRAKE DISARM light illuminates for one to two seconds and then extinguishes, indicating that an automatic self-test has been successfully accomplished.
>
> To arm the RTO mode prior to takeoff the following conditions must exist:
>
> - aircraft on the ground
> - anti-skid and autobrake systems operational
> - AUTO BRAKE select switch positioned to RTO
> - wheel speed less than 60 knots
> - forward thrust levers positioned to IDLE.
>
> With RTO selected, if the takeoff is rejected prior to wheel speed reaching 90 knots autobraking is not initiated, the AUTO BRAKE DISARM light illuminates and the RTO autobrake function remains armed. If the takeoff is rejected after reaching a wheel speed of 90 knots, maximum braking is applied automatically when the forward thrust levers are retarded to IDLE. Braking force is the equivalent of full manual braking.
>
> The AUTO BRAKE DISARM light does not illuminate and the AUTO BRAKE select switch remains in the RTO position. To reset or manually disarm the autobrake system, position the selector to OFF. If a landing is made with RTO selected (AUTO BRAKE select switch not cycled through OFF), no automatic braking action occurs and the AUTO BRAKE DISARM light illuminates two seconds after touchdown.

[24] Revision 06/14/04 #42, Section 6.14, Landing Gear, System Description, Autobrake System, p.28.

1.6.3. Crosswind Guidelines

1.6.3.1. CAL B-737 Crosswind Guidelines

CAL's Boeing B-737 Flight Manual's limitations section[25] contained the following crosswind guidelines.

> Note: The crosswind guidelines presented below were derived through flight test data, engineering analysis, and piloted simulation evaluations. Therefore, the use of these guidelines should be based on the current weather conditions and the pilot's ability and experience level.

Runway Condition	**Crosswind Component (Knots)**
Dry	33
Wet	23
Standing Water / Slush	16
Snow – No Melting*	21

* Takeoff on untreated snow should only be attempted when no melting is present.

1.6.3.2. Boeing B-737 Takeoff Crosswind Guidelines

According to information provided by Boeing, the maximum demonstrated crosswind component for takeoff and landing in the B-737-500 was 35 knots.[26] This figure was demonstrated during the certification, and was not considered limiting on a dry runway with all engines operating. In a supplemental type certificate report, Aero Tec (on behalf of Aviation Partners Boeing, the manufacturer and installer of winglets installed on the accident airplane) subsequently published a maximum demonstrated crosswind component of 22 knots for winglet-equipped B-737-500s.

Boeing's most recent crosswind guidelines for the B-737, published in 1996, are listed in table 13. [27] These guidelines were developed to help airlines develop company policies related to crosswind operations. They were developed using engineering simulations that analyzed the airplane's takeoff and landing performance under "adverse airplane loading conditions and normal piloting techniques." Mathematical models of pilot behavior were used to drive control inputs in the simulations.[28]

The 1996 guidelines increased the landing crosswind component for some runway conditions compared to past publications.[29] However, takeoff crosswind guidelines were not previously published. Prior to 1996, Boeing referenced the demonstrated crosswind

[25] Revision 06/01/08 #46, Section 1, Limitations, Crosswind Guidelines, p.5.
[26] Electronic correspondence with Michael Mock, Boeing Flight Operations Engineering, Boeing Commercial Airplanes, March 19, 2009.
[27] Crosswind guidelines update. *Operations Newsletter: Airliner*. July-September, 2006, i-ii.
[28] These mathematical models of pilot behavior were previously validated in piloted simulator trials using a B-757 simulator.
[29] For example, the landing crosswind guideline for wet runway conditions was increased from 25 knots to 40 knots.

component of 35 knots when providing information about the airplane's crosswind takeoff capabilities.[30]

Table 13.
Boeing B-737-500 crosswind guidelines.

Runway Condition	Takeoff	Landing
Dry	40	40
Wet	25	40
Standing water / slush	16	20
Snow – No melting	21	35
Ice – No melting	7	17

1.10. Airport Information

Denver International Airport, Denver, Colorado, is located about 16 miles northeast of Denver, Colorado. The airport elevation is 5,431 feet mean sea level (MSL). The airport is served by two sets of parallel runways and one set of non-parallel runways, for a total of six runways. The parallel runways are numbered runway 16L-34R, 16R-34L, 17L-35R, and 17R-35L. The non-parallel runways are numbered 7-25 and 8-26. The active runway for CAL flight 1404 on the day of the accident was runway 34R.

1.10.1.Runways

A detailed description of each of the runways at DEN is shown in the following tables:

Denver International Airport (DEN)
Denver, Colorado

DESCRIPTION	RUNWAY			
	16L	34R	16R	34L
DIMENSIONS (FEET)	12,000 x 150	12,000 x 150	16,000 x 200	16,000 x 200
USABLE RUNWAY LENGTH BEYOND GLIDE SLOPE (FEET)	11,006	10,929	14,980	14,910
TOUCHDOWN ZONE ELEVATION (FEET)	5,347.0	5,350.6	5,318.6	5,323.8
SURFACE	Concrete/ Grooved	Concrete/ Grooved	Concrete/ Grooved	Concrete/ Grooved
RVR EQUIPMENT	Touchdown, Midfield, Rollout	Touchdown, Midfield, Rollout	Touchdown, Midfield, Rollout	Touchdown, Midfield, Rollout
APPROACH LIGHTS	MALSR[31]	ALFS-II[32]	MALSR	ALFS-II
TOUCHDOWN ZONE LIGHTS	Yes	Yes	Yes	Yes
RUNWAY EDGE LIGHTS	High Intensity	High Intensity	High Intensity	High Intensity

[30] Electronic correspondence with Darren Jens, Aero Stability and Control, Boeing Commercial Airplanes, on May 14, 2009.
[31] 1,400-foot Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights.
[32] Standard 2400 feet high-intensity approach lighting system with centerline sequenced flashers (CAT II or CAT III)

CENTERLINE LIGHTS	Yes	Yes	Yes	Yes
VISUAL APPROACH SLOPE INDICATOR (VASI)	4-Light PAPI[33] on Left	4-Light PAPI on Left	4-Light PAPI on Right	4-Light PAPI on Left

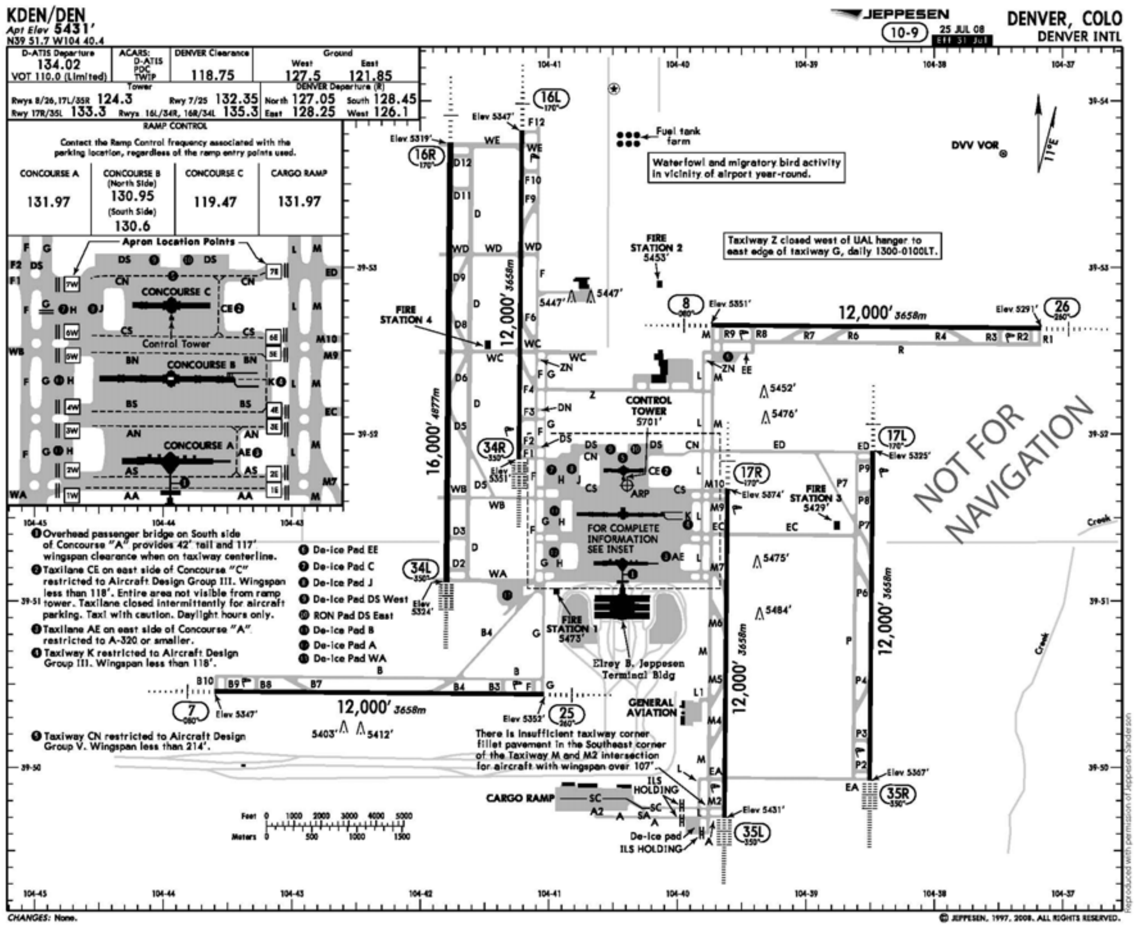
DESCRIPTION	RUNWAY			
	17L	35R	17R	35L
DIMENSIONS (FEET)	12,000 x 150	12,000 x 150	12,000 x 150	12,000 x 150
USABLE RUNWAY LENGTH BEYOND GLIDE SLOPE (FEET)	11,015	10,874	11,035	10,899
TOUCHDOWN ZONE ELEVATION (FEET)	5,324.8	5,366.7	5,374.4	5,430.5
SURFACE	Concrete/ Grooved	Concrete/ Grooved	Concrete/ Grooved	Concrete/ Grooved
RVR EQUIPMENT	Touchdown, Midfield, Rollout	Touchdown, Midfield, Rollout	Touchdown, Midfield, Rollout	Touchdown, Midfield, Rollout
APPROACH LIGHTS	MALSR	ALFS-II	MALSR	ALFS-II
TOUCHDOWN ZONE LIGHTS	Yes	No	Yes	Yes
RUNWAY EDGE LIGHTS	High Intensity	High Intensity	High Intensity	High Intensity
CENTERLINE LIGHTS	Yes	Yes	Yes	Yes
VISUAL APPROACH SLOPE INDICATOR (VASI)	4-Light PAPI on Left	4-Light PAPI on Right	4-Light PAPI on Left	4-Light PAPI on Right

DESCRIPTION	RUNWAY			
	7	25	8	26
DIMENSIONS (FEET)	12,000 x 150	12,000 x 150	12,000 x 150	12,000 x 150
USABLE RUNWAY LENGTH BEYOND GLIDE SLOPE (FEET)	10,958	10,941	10,899	11,042
TOUCHDOWN ZONE ELEVATION (FEET)	5,346.8	5,351.8	5,351.2	5,291.1
SURFACE	Concrete/ Grooved	Concrete/ Grooved	Concrete/ Grooved	Concrete/ Grooved
RVR EQUIPMENT	Touchdown	Touchdown	Touchdown	Touchdown
APPROACH LIGHTS	MALSR	MALSR	MALSR	MALSR
TOUCHDOWN ZONE LIGHTS	Yes	Yes	Yes	Yes
RUNWAY EDGE LIGHTS	High Intensity	High Intensity	High Intensity	High Intensity
CENTERLINE LIGHTS	Yes	Yes	Yes	Yes
VISUAL APPROACH SLOPE INDICATOR (VASI)	4-Light PAPI on Right	4-Light PAPI on Left	4-Light PAPI on Left	4-Light PAPI on Left

[33] Precision Approach Path Indicator

1.10.2. Airport Diagram 10-9

The DEN airport diagram is reproduced below.



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1.13. Medical and Pathological Information

1.13.1. The Captain's Medical Information

The captain's most recent FAA first-class medical certificate was issued September 16, 2008. It bore no limitations. It indicated that he was 68 inches tall and weighed 200 pounds. His FAA medical certification records indicated that he was not taking any prescription medications and that his medical certification had never been denied or suspended.

The captain told investigators his health was generally good before the accident. He stated that he had lost 25 pounds and gotten in shape during the previous 12 months. He said he was exercised regularly and was physically fit.

The captain said that, in the 72 hours before the accident, he did not take any medications, prescription or nonprescription. He said that he occasionally drank alcohol and that his last use consisted of two beers consumed on December 17, 2008. He said that he occasionally used tobacco products in the form of cigars and that his last use occurred on December 17, 2008.

A blood sample was collected from the captain at 1945 on December 20, 2008, by medical personnel at Denver Health, a hospital where the captain was admitted for treatment of injuries he sustained in the accident. A portion of this sample was sent to the FAA Civil Aerospace Medical Institute for toxicological testing. The sample tested negative for ethanol (alcohol) and a variety of legal and illegal drugs.[34]

1.13.2. The First Officer's Medical Information

The first officer's most recent FAA first-class medical certificate was issued March 12, 2008. It bore no limitations. It indicated that he was 75 inches tall and weighed 229 pounds. His FAA medical certification records indicated that he was not taking any prescription medications and that his medical certification had never been denied or suspended.

The first officer told investigators he was "a fairly healthy individual." He reported breaking a tooth on December 11, 2008 and said he underwent a dental procedure to repair it on December 14, 2008. He said he was not prescribed and he did not use any prescription pain medication after the day of the procedure. He also stated that he had not experienced any oral pain after the day of the procedure. He reported no other significant changes to his health in the previous 12 months.

The first officer stated that, in the 72 hours before the accident, he did not take any

[34] Immunoassay and chromatography were used to screen for the following drugs: amphetamine, opiates, marihuana, cocaine, phencyclidine, benzodiazepines, barbiturates, antidepressants, antihistamines, meprobamate, methaqualone, and nicotine.

medications, prescription or nonprescription. He said he did not drink alcohol. He said he used tobacco products in the form of chewing tobacco and that his last use occurred on the morning of the accident.

The first officer submitted a urine sample on December 21, 2009, as required under CAL's drug and alcohol testing program.[35,36] The sample tested negative for the presence of several drugs of abuse.[37]

1.16. Tests and Research

1.16.1. Observational Study in a CAL B-737-500 Training Simulator

The operational factors / human performance group performed an observational study in a B-737-500 level D training simulator at a CAL pilot training facility in Houston, Texas on January 27, 2009. The purpose of the study was to familiarize the group with company standard operating procedures pertaining to crosswind takeoffs, to evaluate the effect of varying crosswind conditions on the subjective difficulty of takeoffs in the simulator, and to evaluate the effect of various control inputs on simulator response during crosswind takeoffs and rejected takeoffs.

1.16.1.1. Crosswind Takeoff Procedures

Crosswind takeoff procedures were demonstrated by two CAL assistant Boeing B-737 fleet managers. These managers were type rated and current in the B-737-500. The following direct left crosswind conditions were used for the demonstrations: 0 knots, 25 knots, 35 knots, and 31 gusting to 37 knots. Simulator motion was turned off so that all group members could simultaneously observe the demonstrations inside the simulator cab. During these crosswind takeoffs, the manager who served as the flying pilot used left aileron correction and variable right rudder correction as the airplane accelerated down the runway. At rotation, he reduced the left control wheel correction and pulled the control column aft. He then used the control wheel to keep the wings level as he neutralized the rudder. He reported that the takeoffs were more difficult with the simulator motion turned off, because the motion was useful for cueing control inputs.

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[35] 14 Code of Federal Regulations Part 121, Appendix I *Drug Testing Program* states that "Each employer shall test each employee who performs a safety-sensitive function for the presence of marijuana, cocaine, opiates, phencyclidine (PCP), and amphetamines, or a metabolite of those drugs in the employee's system if that employee's performance either contributed to an accident or can not be completely discounted as a contributing factor to the accident. The employee shall be tested as soon as possible but not later than 32 hours after the accident."

[36] 14 Code of Federal Regulations Part 121, Appendix J *Alcohol Misuse Prevention Program* states that "As soon as practicable following an accident, each employer shall test each surviving covered employee for alcohol if that employee's performance of a safety-sensitive function either contributed to the accident or cannot be completely discounted as a contributing factor to the accident."

[37] The sample was screened for the following drugs of abuse: marijuana, cocaine, opiates, phencyclidine, and amphetamines.

1.16.1.2. Strength of Crosswind and Subjective Difficulty of Takeoff

Five group members with ATP certificates (four of whom were type rated in the B-737) flew simulated takeoffs in the following direct left crosswind conditions: 0 knots, 25 knots, 35 knots, and 30 gusting to 40 knots. Winds were presented in a counterbalanced order. Simulator motion was turned on. The flying pilot sat in the left seat.

Participants provided a subjective characterization of the difficulty of the takeoffs using a 5-point rating scale ranging from 1 (“very easy”) to 5 (“very difficult”). The majority of participants judged the 0-knot crosswind condition as very easy, the 25-knot condition as neither easy nor difficult, and the 35 knot and 30 gusting to 40 knot conditions as slightly difficult.

1.16.1.3. Takeoff and Rejected Takeoff Scenarios

Each of the group’s five ATP-certificated group members performed the takeoff and rejected takeoff scenarios listed below. The flying pilot sat in the left seat. Simulator motion was turned on. Each takeoff roll was begun normally.

1. Removed the feet from rudder pedals at 90 knots.
2. Removed the feet from rudder pedals at 90 knots (rudder trim adjusted to 1.5 degrees left).
3. Removed the feet from rudder pedals at 90 knots. Moved the control wheel full right at 100 knots.
4. Removed the feet from rudder pedals at 90 knots. Tried to maintain directional control using the tiller.
5. Removed the feet from rudder pedals at 90 knots. Waited 2 seconds (until a signal given by an observer with a stopwatch). Resumed rudder inputs and tried to complete the takeoff.
6. Removed the feet from rudder pedals at 90 knots. Waited 3 seconds (until a signal given by an observer with a stopwatch). Resumed rudder inputs and tried to complete the takeoff.
7. Removed the feet from rudder pedals at 90 knots. waited 2 seconds (until a signal given by an observer with a stopwatch). Resume rudder control inputs and tried to perform a rejected takeoff.
8. Began the takeoff roll normally. Removed the feet from rudder pedals at 90 knots. Waited 3 seconds (until a signal given by an observer with a stopwatch). Resumed rudder inputs and tried to perform a rejected takeoff.

The outcomes of these scenarios are summarized below.

1. The airplane began turning left after the removal of right rudder correction and it exited the left side of the runway about 5 seconds later. Tire scrubbing vibrations and sounds began just before exiting the runway. The airplane left the runway at the 9,000-feet-remaining marker at an airspeed of about 120 knots.
2. The outcome was similar to scenario 1, except the tire scrubbing vibrations and

sounds began halfway between the centerline and the side of the runway, and the left turn was more rapid. The airplane left the runway a fraction of a second earlier, about 300 feet before the 9,000-feet-remaining marker.

3. The outcome was the same as scenario 1.
4. The outcome was similar to scenario 1, except tire scrubbing vibrations and sounds were stronger and began soon after the application of tiller, the turn was less rapid, and the airplane exited the runway several hundred feet beyond the 9,000-feet-remaining marker.
5. All of the participants were able to salvage the takeoff. Three considered this scenario moderately difficult. Two considered it neither difficult nor easy.
6. Three participants were able to salvage the takeoff. Two were unable to rotate before the airplane departed the runway. Four described the scenario as very difficult. A fifth described it as slightly difficult.
7. All participants were able to reject the takeoff with skidding or "fishtailing" on the runway. Three described the scenario as slightly difficult. Two described it as moderately difficult.
8. Three participants were able to reject the takeoff with extreme skidding or "fishtailing." Two were unable to keep the airplane from departing the runway. All participants described the scenario as very difficult.

1.16.1.4. Participant Observations

Study Participants agreed on a list of general observations, including the following.

- The simulator was not good as good as the real airplane at providing a seat of the pants feel for wind gusts. It did not seem to accurately reflect lateral acceleration.
- Maintaining the runway centerline was consistently achievable with direct crosswinds as high as 30 gusting to 40 knots.
- At high speeds (over 90 knots), steering with tiller had a very small effect on the airplane's ground track.
- Taking off in 35 or more knots of crosswind required continuous adjustment and monitoring of rudder correction.
- Participants tended to make rudder pedal inputs in response to perceived changes in heading and then quickly reduce the inputs as the airplane began to respond.
- The amount of right rudder pedal input required to maintain the runway centerline in a high left crosswind (35 knots) felt like 1/3 to 1/2 of the pedals' range of travel.
- During takeoff roll in a 35-knot direct left crosswind, a 2-second pause in rudder pedal inputs beginning at 90 knots caused the airplane to turn left. When rudder correction resumed, it was possible to keep the airplane on the runway with full-travel pedal inputs and then continue or reject the takeoff.
- During takeoff roll in a 35-knot direct left crosswind, a 3-second pause in rudder pedal inputs beginning at 90 knots caused a bigger left turn. The group judged this situation to be unmanageable for a line pilot who was not expecting it.

1.16.2. Operational Information Provided by Continental Airlines

CAL provided statistical information about crosswinds and heading stability for a large sample of takeoffs performed in CAL airplanes. This information included the following points.

- Takeoffs with a crosswind component of 30 or more knots constituted 0.0066% of 940,400 takeoffs for all CAL airplane types, and 0.00002% of 250,327 takeoffs involving B-737-500s.[38]
- More heading movement was seen during takeoff roll for the B-737-500 compared to other B-737 variants.[39] Heading movement did not increase as winglets were installed on the B737-500s.[40]
- B-737-500 rudder travel range recorded during flight control checks was about plus or minus 24.5 degrees. Average rudder displacement during takeoff roll of 5.2 degrees or greater occurred in 0.026% of takeoffs.[41] Rudder movement tended to peak during the winter and early spring months (December through March).
- B-737-500 rudder pedal travel recorded during flight control checks was about plus or minus 12.5 degrees. When data on rudder pedal movements recorded 15 to 3 seconds before takeoff were analyzed, the mean plus two standard deviations was 2.56 degrees.
- High-crosswind takeoff rolls in the B-737-500 were characterized by oscillating rudder pedal inputs that decreased in amplitude as the airplane approached rotation speed. [42]
- For a sample of 10 B-737-500 high-crosswind takeoff rolls, the average interval between peak rudder inputs was 4.5 seconds. For a sample of 10 B-737-500 moderate-crosswind takeoff rolls, the average interval between peak rudder inputs was 4.8 seconds.[43]

1.16.3. Operational Information Provided by United Airlines

United Airlines provided statistical information about crosswinds encountered during a large sample of takeoffs performed in its airplanes. This information included the following points.

[38] Crosswind component was calculated using flight parameters recorded 7 seconds after takeoff and the following formula: CROSSWIND = (WIND SPEED) * sin { (HEADING – (WIND DIRECTION)) * pi/180 }. Calculated crosswind component was highly correlated with average rudder correction 15 to 3 seconds before liftoff (r = .81). Takeoffs for all CAL airplanes, except the B-737-300 were included in this analysis.

[39] Heading movement was the maximum minus the minimum heading. Data recorded between 70 and 110 knots were used for the analysis. This analysis did not include data from B-737-300 airplanes.

[40] Winglets were installed on the B-737-500 airplanes between May 2007 and January 2009.

[41] Data recorded between 15 and 3 seconds before liftoff were used for this analysis.

[42] High crosswind takeoff was defined as a crosswind takeoff with a calculated crosswind component greater than 20 knots 7 seconds after takeoff and an average rudder pedal position during the period 15 to 3 seconds before takeoff of more than 4 degrees (positive or negative).

[43] Moderate crosswind takeoff was defined as a crosswind takeoff with a calculated crosswind component greater than 10 knots but less than 20 knots 7 seconds after takeoff and an average rudder pedal position during the period 15 to 3 seconds before takeoff between 3 and 4 degrees (positive or negative).

- Takeoffs with a crosswind component greater than 30 knots constituted 0.014% of 563,043 takeoffs system-wide.[44]
- Takeoffs with a crosswind component greater than 30 knots constituted 0.057% of 77,526 takeoffs at Denver International Airport.

1.17. Organizational and Management Information

1.17.1. Continental Airlines Fleet Composition

At the time of the accident, CAL operated a fleet of 368 airplanes, listed by type and variant in Table 14.

Table 14.
Continental Airlines Fleet Composition at the Time of the Accident.

Airplane Type or Variant	Number of Airplanes
B-737-300	32
B-737-500	48
B-737-700	36
B-737-800	117
B-737-900	31
B-757-200	41
B-757-300	17
B-767-200	10
B-767-400	16
B-777-200	20

1.17.2. Continental Airlines Safety Programs

CAL maintained a flight safety office with a staff of four full-time and three part-time employees. The company's director of flight safety and regulatory compliance, who ran the office, had served in that role for over 23 years. He reported to the staff vice president for safety, who had a direct line of communication to the chief executive officer but was supervised on a day to day basis by the executive vice president for operations.

The flight safety office oversaw the airline's flight safety programs. These included: the CAL Safety Information System (CASIS), the line operations safety audit (LOSA) program, the flight operations quality assurance (FOQA) program, and the aviation safety action program (ASAP). The flight safety office used the data generated through these programs to support the airline's safety management system. In addition, the flight safety office was responsible for performing safety investigations of flight safety-related incidents and accidents.

CAL created its CASIS safety database in 1996 to replace an older system. It

[44] United Airlines reported that crosswind component was calculated as follows: {[Wind Speed (knots)]*sin(if_exists([Track Angle (true) (deg)],if_exists([Heading (true)(deg)],[Heading (magnetic) (deg)])+if_exists([Drift Angle(deg)],0))-[Wind Direction (true) (deg)])}. True heading was utilized for Airbus and B-767 and B-777 airplanes. Track angle was used for B-737 and B-747 airplanes.

contained irregularity reports filed by the airline's captains and duty directors. The flight safety department held weekly operational safety investigation meetings to review reports entered into CASIS and classify the risks posed by the reported issues. During the meetings, the need for follow-up actions was determined and progress on previous action items was assessed.

The LOSA program began in 1993. Its purpose was to monitor safety and to identify safety issues during routine flight operations. Since the beginning of the program, the company had conducted four comprehensive safety audits (one every four years) and several smaller-scale audits. The results of the most recent comprehensive audit were presented to company executives in January 2009. The findings of the audits were used by the flight safety office to identify needed safety improvements.

CAL's FOQA program began in 1996. Its purpose was to provide flight operational quality assurance by electronically monitoring all aircraft operations. The airline had installed quick access recorders (QARs) on all airplanes, except the B-737-300, to record a variety of flight parameters. These recorders were downloaded on a regular basis and the data transferred to the flight safety department. Data from individual flights were stripped of identifying information by "gatekeepers" from the pilots' union and then used by the company to identify safety issues, monitor trends and spur safety improvements.

The ASAP program had been in place since 1998. Its purpose was to allow the company to learn about flight safety-related issues identified by line pilots. Pilots could submit ASAP reports to the flight safety department electronically, and the program provided them some immunity from disciplinary action. An event review committee (ERC), consisting of representatives of the pilots' union, flight safety department, and the FAA, reviewed the reports on a bi-weekly basis. In some cases, members of the committee contacted reporters to obtain more information. The ERC issued recommendations to appropriate departments within the airline and to outside organizations as well.

1.18. Additional Information

1.18.1. Prior CAL Accidents and Incidents

1.18.1.1. Runway Excursions

CAL provided investigators internal reports describing three previous events involving B-737-500 airplanes that had departed the side of the runway. All three events occurred during the landing roll.

1.18.1.1.1. Accident at Guadalajara on September 16, 1998

On September 16, 1998, at 2253 central daylight time, a Boeing 737-524 transport airplane, N20643, operating as CAL flight 475, was substantially damaged following a loss of control during the landing roll at the Don Miguel Hidalgo International Airport near Guadalajara, Mexico. The 2 airline transport rated pilots, the 4 flight attendants, and the

102 passengers were not injured. The airplane was being operated under Title 14 CFR Part 121. Night visual meteorological conditions prevailed for the scheduled international passenger-cargo flight for which an IFR flight plan was filed. The flight was dispatched from the George Bush International Airport near Houston, Texas, at 2056, for the two hour flight to Guadalajara, State of Jalisco, Mexico. The flight's scheduled arrival time was 2254. This accident was investigated by the Government of the Republic of Mexico, which has not released any conclusions. CAL safety information systems contained the following description of this accident.

> The aircraft departed the left side of the runway while landing in heavy rain and winds. The aircraft that landed just before the Continental flight had also departed the left side of the runway momentarily, but the pilot was able to regain control. The nose-gear collapsed as the aircraft departed the runway, causing serious structural damage. Crew error in attempting to land in crosswinds beyond the aircraft's capability.

1.18.1.1.2. Incident at Newark on January 28, 2000

CAL safety information systems contained a description of the following incident, involving a B-737-500 at Newark International Airport.

> Upon touchdown the aircraft veered to the left. Despite the crew's efforts to straighten the aircraft out using full right rudder, full right brake, and right tiller, the drift would not stop. The aircraft departed left side of runway into snow-covered grass. The were no injuries and no aircraft damage. Crew suspected that a faulty left brake caused the excursion. Mx checked brakes and found no problems. Mx R&R CVR and FDR. After aircraft was towed from runway, the tow bolt was found worn and was R&R.

1.18.1.1.3. Incident at Gulfport on September 21, 2003

CAL safety information systems contained a description of the following incident involving a B-737-500 at Gulfport-Biloxi International Airport.

> Approached GPT from the west with thunderstorms in area. Upon touchdown hit heavy rain with right drift and runway contact simultaneously. A/C drifted right and gear migrated to the side. Steered A/C back to centerline and rolled to a slow stop while assessing aircraft condition. Called tower and advised. Asked for trucks to look for damage. None seen at that time. Taxied to gate. Did inspection at gate and found scrapes under #1 engine and damage to thrust reverser sleeve.

1.18.1.2. Other Incidents

CAL’s flight safety department staff searched CASIS for reports of difficulty maintaining directional control on the runway. They identified a number of incidents that were caused by minor mechanical problems. The search also identified four incidents that did not clearly result from a mechanical cause. These are summarized below.

- In October 2006, a B-737-300 flight crew performed a rejected takeoff at 90 knots when they were unable to maintain directional control during the takeoff roll, despite full rudder pedal inputs. The flight crew informed the tower that the problem was due to high crosswinds and windshear.

- In July 2005, a B-737-500 flight crew reported having to use considerable left rudder to keep the airplane on the centerline during a landing roll because the airplane was yawing to the right. Maintenance identified no problems with the airplane's mechanical systems.
- In May 2005, a B-737-500 flight crew reported that the left rudder pedal moved halfway to the floor and the airplane yawed abruptly to the left at 125 knots during a takeoff roll in calm winds. The yaw was corrected with right rudder and the problem went away. Although no mechanical defects were found with the airplane, some rudder components were replaced as a precaution. Jetwash from a nearby taxiway was cited as a possible cause of the incident.
- In November 2002, a B-737-500 captain undergoing initial operating experience performed a rejected takeoff because of "yawing" experienced during the early part of a takeoff roll. The check airman flying with the captain described the airplane's behavior as normal "yawing" that can occur during the early stage of a takeoff roll on a slippery runway in light to moderate rain and he attributed the captain's decision to a lack of familiarity with this characteristic of the B-737-500.

E. LIST OF ATTACHMENTS

Attachment 1: Interview Summaries

Attachment 2: Flight Crew Statements

Attachment 3: Operational Study

Attachment 4: Flight Papers

Attachment 5: Flight Manual Excerpts

Attachment 6: Operational Information Requested by NTSB