NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

April 24, 2016

Group Chairman's Factual Report

OPERATIONAL FACTORS

DCA15FA085

Contents

A. ACCIDENT

Operator: Delta Air Lines (Delta)
Location: New York, New York
Date: March 5, 2015
Time: 1103 Eastern Standard Time (EST)[1]
Airplane: Boeing MD88, N909DL

B. OPERATIONAL FACTORS GROUP

Captain David Lawrence – Chairman[2]
Operational Factors Division (AS-30)
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594-2000

Dr. William Bramble
Human Performance Division (AS-60)
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594-2000

Mr. Michael Nash
Aviation Safety Inspector - Operations
Long Beach Aircraft Evaluation Group
Federal Aviation Administration (FAA)
Lakewood, CA 90712

Captain Steve Acalin
MD88/90 Line Check Airman
Delta Air Lines
980 Virginia Ave.
Atlanta, GA 30354

Captain Brian Teske
Safety Representative
Air Line Pilots Association
100 Hartsfield Centre Pkwy #800
Atlanta, GA 30354

Captain James Brocksmith
Safety Pilot
P.O. Box 3707
The Boeing Company
Seattle, Washington 98124

[1] All times are eastern standard time, except as noted.
[2] Captain Roger Cox (NTSB) was the Operations Group Chairman for this investigation until his retirement in March 2016.

C. SUMMARY

On March 5, 2015, about 1102 eastern standard time (EST), a Boeing MD-88, N909DL, operating as Delta flight 1086, was landing on runway 13 at LaGuardia Airport, New York, New York (LGA), and exited the left side of the runway, contacted the airport perimeter fence, and came to rest with the airplane nose on an embankment next to Flushing Bay. The 129 passengers received either minor injuries or were not injured, and the 3 flight attendants and 2 flight crew were not injured. The airplane was substantially damaged. Flight 1086 was a regularly scheduled passenger flight from Hartsfield-Jackson Atlanta International Airport (ATL) operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121. Instrument meteorological conditions (IMC) prevailed, and an instrument flight rules (IFR) flight plan was filed.

D. INVESTIGATION

The Operations and Human Performance group was formed on March 6, 2015 and prepared to travel to New York. Upon consultation with Delta officials, the accident flight crew was released to return to Atlanta and the Operations and Human Performance group traveled to and assembled in Atlanta. Interviews with the flight crew were conducted on March 7, 2015 and interviews with Delta management personnel and company pilots were conducted from March 9 to March 12, 2015.

Flight documents and company manuals were obtained from Delta and the Boeing Company. Flight crew certification records were obtained from the FAA.

E. FACTUAL INFORMATION

1.0 History of the Flight

The flight crew reported for duty on the day of the accident at 0500 in Daytona Beach, Florida (DAB) and flew to ATL, arriving at 0705. The accident flight was scheduled to depart ATL at 0845 but was delayed about 20 minutes for minor maintenance. The planned enroute flight time was one hour thirty minutes, and the weather forecast for LGA for the time of arrival was winds 300 degrees at 12 knots, visibility one half statute mile in snow and mist, with broken clouds at 700 ft. above ground level (agl). Two alternate airports were designated in the flight release[3]. The crew obtained ACARS[4] reports of the current ATIS[5] information for LGA while at the departure gate. Both the captain and the FO (first officer) consulted the MD88 Operational Data

[3] See Attachment 2 - Flight Release, NOTAM's, Weather Forecast. NOTAM – Notice to Airmen.

[4] Aircraft Communication Addressing and Reporting System (ACARS) is a digital datalink system for Transmission of short, relatively simple messages between aircraft and ground stations via radio or satellite.

[5] Automatic Terminal Information Service (ATIS) is the continuous broadcast of recorded noncontrol Information in selected high activity terminal areas. Its purpose is to improve controller effectiveness and to relieve frequency congestion by automating the repetitive transmission of essential but routine information. The information is continuously broadcast over a discrete VHF radio frequency or the voice portion of a local NAVAID. Arrival ATIS transmissions on a discrete VHF radio frequency are engineered according to the individual facility requirements, which would normally be a protected service volume of 20 NM to 60 NM from the ATIS site and a maximum altitude of 25,000 feet agl. Source: Aeronautical Information Manual, Section 4-1-13.

Manual (ODM) and determined, based on the current and forecast conditions at LGA, they would need a braking action report of "good" in order to safely land at LGA.

During the flight the crew monitored conditions at LGA, checking the ATIS via ACARS updates as it changed and asking the flight dispatcher for braking action reports[6]. At 0955, 33 minutes after takeoff, the crew requested and received a field condition report which stated braking action advisories were in effect. Taxiways were reported to have 3 ft. snowbanks along their edges and runways were reported to be wet and sanded, and deiced with solid chemical. At 1018 the crew sent the dispatcher a message which said, "NEED BRAKING ACTION REPORTS FOR LGA. WE CAN ONLY LAND WITH GOOD. ANYTHING LESS THAN THAT WE ARE OVER WEIGHT." The dispatcher replied "I'LL PASS THE BRAKING ACTION ALONG AS SOON AS I GET ONE…PORT AUTHORITY IS PRESENTLY WORKING ON RWY 13."

The captain, who was the pilot flying (PF), briefed the FO they would fly the ILS (instrument landing system) runway 13 approach using flaps 40 and maximum autobrake for landing. As the flight approached Robbinsville (RBV) VOR[7], ATC (air traffic control) informed the crew LGA was closed for snow removal and to expect holding instructions. In an ACARS message to the dispatcher, the captain expressed surprise that LGA runway 13 was closed. Shortly thereafter ATC cleared the flight to continue the KORRY arrival. At 1042, the flight contacted New York approach control and advised they had ATIS information "P", which included winds from 040 degrees at 7 knots, ¼ statute mile visibility in snow and freezing fog, and a variable ceiling at 900 feet agl. As they continued the descent, ATC reported braking action was reported "good" by both an Airbus and a regional jet.[8] The FO stated he felt this was a "green light" for the runway being satisfactory to land. At 1050 the dispatcher sent the flight an ACARS message saying runway 13 was open and braking action had been reported "good" by a flight which had just landed. ATC vectored the flight to intercept the final approach course at 3,000 ft. mean sea level (msl) and cleared the flight to fly the ILS 13 approach.

The captain stated he monitored the FMS[9] wind display during the approach and noted there was a 10 to 11 knot tailwind which changed to a quartering tailwind as they continued. At 1059, New York approach control advised the crew that the runway visual range (RVR) for runway 13 was greater than 6,000 feet, with the rollout RVR at 4,000 feet. According to an ATC recording, the tower controller reported the wind as 020 degrees at 10 knots shortly before the airplane landed. The captain stated he saw the approach lights at around 400 ft. msl and the runway at about 300 ft. msl. The FO called out "approaching minimums" and the captain said "runway in sight." Both pilots stated they saw the runway centerline lights but the runway was white in color and appeared to be covered in snow, which they did not expect.

The captain stated when he saw the runway he adjusted his aim point to get the airplane on the ground as soon as possible, and as a result they landed within the first 1,000 ft. of the runway and on centerline.[10] When they touched down, he lowered the nose to the ground and moved the

[6] See Attachment 3 - Enroute ACARS Communication.
[7] Very high frequency omni range.
[8] See Section 8.1 Braking Action Reports of this Factual Report.
[9] Flight management system.
[10] As discussed in FAA-H-8083-3A, the target touchdown point is defined as a touchdown point approximately

thrust reverser levers up to idle. According to the captain, he set one knob width on the reverser handle in order to obtain the desired setting of 1.3 EPR[11]. According to the FO, the speed brake did not automatically deploy, so he manually deployed it. The airplane began to slide left and the captain directed his attention outside the airplane. He did not hear the normal braking sound or feel the usual deceleration and he did not look at the EPR indicators. According to the captain, the FO called out "watch your reverse, you're drifting left," and the captain reduced reverse thrust. According to the captain, the airplane did not respond to his efforts to steer the nose back to the right and they departed the left side of the runway.

The FO estimated their speed to be about 80 knots when they departed the runway. He stated the airplane continued to slide and the left wing appeared to be caught on a retaining wall. He was concerned they would go in the water, so without asking permission, he shut down the engines to prevent any further thrust from pushing them over into the water. The captain stated the airplane's nose broke through the fence on the wall and they could see the drop off and the water below as they came to a stop.

There was no electrical power on the airplane and the crew's attempts to switch on emergency power and start the APU were unsuccessful. They were unable to communicate via radio or interphone. After opening the cockpit door, the captain spoke with the forward flight attendant and told her to assess the doors. He then left his seat and went to the cabin. The FO used his cell phone to call Delta dispatch, which transferred the call to the LGA tower. He reported the persons on board count and fuel quantity on board. The flight crew ran the parts of the evacuation checklist that could be accomplished without power. Firefighters approached the FO's partially open side window and told the FO everyone should evacuate via the right over wing exits due to fuel leaking from the left wing. The captain ordered an evacuation and the flight attendants began evacuating the passengers through the right over wing exits and the tail cone and the flight crew assisted. After checking to see all passengers were off the airplane, the captain and FO exited through the tail cone.

2.0 Flight Crew Information

2.1 The Captain

The captain, who was 56 years of age, had been continuously employed at Delta since August 14, 1989, and had been a captain on the MD88/90[12] for 14 years. He initially qualified as captain on the MD88/90 on January 31, 2001. He had formerly flown in the U.S. Air Force and he stated he had 11,000 hours flight experience on the MD88/90. He had also flown the B727 and B767 while at Delta.

1,000 feet down the runway, after which maximum braking effort must be applied if the manufacture's predicted landing distance is to be obtained. According to FAA Advisory Circular 91-79, dated November 6, 2007, as referenced in the Air Traffic Rules and Procedures Service (ATP) Practical Test Standards Guide, the touchdown zone is defined as a point 500-3,000 feet beyond the runway threshold not to exceed the first one-third of the runway. This definition is not used in landing distance performance calculations.

[11] Engine pressure ratio. EPR is used for reading engine thrust on the MD88.

[12] Delta operated both the MD88 and MD90 airplanes. The MD90 was slightly longer than the MD88 and had different engines.

A Delta pilot who flew with the accident captain stated he was professional, was always current on policies and procedures, and was very standardized in handling the airplane. An instructor pilot recalled the captain was very well prepared for training, was experienced and worked well with people. A third pilot recalled that the captain was health conscious and a good family man. Another Delta FO stated the captain was prepared, careful, calm and friendly and followed standard operating procedures.

The captain's FAA medical certificate required him to wear corrective lenses for near and distant vision. He stated in an interview he was wearing his glasses at the time of the accident. According to a review of FAA PTRS[13] information, the captain had no record of prior accidents, incidents, or violations.

2.1.1 The Captain's Pilot Certification Record

FAA records indicated the following certificates were issued to the captain:

Student Pilot – glider-aero tow only certificate issued May 31, 1979

Commercial Pilot – Airplane Multiengine Land limited to center thrust – instrument airplane certificate issued August 26, 1984

Airline Transport Pilot – Airplane Multiengine Land certificate issued May 14, 1989

Flight Engineer – Turbojet Powered certificate issued October 13, 1989

Airline Transport Pilot – Airplane Multiengine Land – B757, B767 type certificate issued April 28, 1997

Airline Transport Pilot – Airplane Multiengine Land – DC9[14], B757, B767 type certificate issued January 31, 2001

2.1.2 The Captain's Certificates and Ratings at the Time of the Accident

Airline Transport Pilot dated December 26, 2009
Airplane Multiengine Land
DC9, B757, B767

Flight Engineer dated October 13, 1989
Turbojet Powered

[13] The Program Tracking and Reporting Subsystem (PTRS) was a comprehensive information management and analysis system used in many Flight Standards Service (AFS) job functions. It provides the means for the collection, storage, retrieval, and analysis of data resulting from the many different job functions performed by Aviation Safety Inspectors (ASIs) in the field, the regions, and headquarters. This system provides managers and inspectors with the current data on airmen, air agencies, air operators, and many other facets of the air transportation system. Source: FAA.

[14] The MD88/90 were common types to the DC9 series airplanes. For additional information, see FAA Order 8900.1, Figure 5-88 "Pilot Certification Aircraft Type Designations – Airplane."

FAA Medical Certificate dated January 5, 2015

First Class

Limitation: Must wear corrective lenses for near and distant vision

2.1.3 The Captain's Training and Proficiency Checks Completed[15]

The captain's recent training history based on Delta records:

Date of Hire (Delta)	August 14, 1989
Date Upgraded to Captain on MD88	January 31, 2001
Date of Initial Type Rating on MD88	January 31, 2001
Date of Most Recent Maneuvers Validation [16]	November 19, 2014
Date of Most Recent SPOT Training[17]	November 19, 2014
Date of Most Recent LOE[18]	February 27, 2014
Date of Most Recent Recurrent Ground Training	November 18, 2014
Date of Most Recent PIC Line Check	November 12, 2014

2.1.4 The Captain's Flight Times

The captain's flight times based on Delta records and pilot statements:

Total flight time:	15,203 hours
Total Pilot-in-Command (PIC) time:	9,690 hours
Total MD88/90 time:	11,687 hours
Flight time last duty period:	3.8 hours
Flight time last 30 days :	56 hours
Flight time last 60 days:	120 hours
Flight time last 90 days:	165 hours
Flight time last 365 days:	702 hours

[15] Delta pilots trained under Advanced Qualification Program (AQP). AQP provides an alternate method of qualifying and certifying, if required, pilots, flight engineers, flight attendants, aircraft dispatchers, instructors, evaluators, and other operations personnel subject to the training and evaluation requirements of Parts 121 and 135. AQP is a systematic methodology for developing the content of training programs. AQP incorporates data-driven quality control processes for validating and maintaining the effectiveness of curriculum content. AQP encourages innovation in the methods and technology that are used during instruction and evaluation, and efficient management of training systems. Source: FAA Advisory Circular (AC) 120-35C.

[16] This validation addresses the individual's proficiency in the execution of maneuvers. It must take place in a simulator. For a qualification curriculum, crewmembers are expected to have reached a satisfactory level of proficiency in the maneuvers prior to the validation event. Source: FAA AC-120-54A.

[17] Special Purpose Operational Training (SPOT). SPOT is a simulator training session designed to address specific training objectives. Training objectives are based on technical and CRM requirements, and include specific training objectives to be critiqued and debriefed on both technical and CRM performance. SPOT may consist of full or partial flight segments depending on the training objectives for the flight. Source: AC 120-35C.

[18] Line Operational Evaluation (LOE). LOE is an evaluation of individual and crew performance in a flight simulation device conducted during real-time. LOE is primarily designed in accordance with an approved design methodology for crewmember evaluation under an AQP. Source: FAA AC 120-35C.

2.2 The First Officer

The FO was 46 years of age. He had been assigned to fly the MD88 for four years and estimated 4,000 of his total of 11,000 flight hours were on the MD88. Before joining Delta on September 3, 2007, he had flown for American Airlines and the U.S. Navy. He retired from the Navy after 21 years of service.

A captain who had flown with the FO recently stated his ability to interact with him was very good and he was obviously very comfortable in what he was doing and very capable. This captain stated the FO was a "super guy" who had made a great landing when they flew together and was precise in his application of reverse thrust during landing. Another captain who had flown with the FO stated the FO was very skilled and made the trip very easy and enjoyable. He recalled the FO's landing as being "flawless."

According to a review of FAA PTRS information, the FO had no record of prior accidents, incidents, or violations.

2.2.1 The First Officer's Pilot Certification Record

FAA records indicated the following certificates were issued to the FO:

Private Pilot – Airplane Single Engine Land certificate issued July 25, 1991

Commercial Pilot – Airplane Multiengine Land – instrument airplane – private pilot privileges – airplane single engine land certificate issued February 4, 1994

Airline Transport Pilot – Airplane Multiengine Land – private pilot privileges – airplane single engine land certificate issued August 29, 2000

Flight Engineer – Turbojet Powered certificate issued June 18, 2001

Airline Transport Pilot – Airplane Multiengine Land – B737 type - private pilot privileges – airplane single engine land certificate issued November 15, 2007
Limitations: B737 circling approach- VMC only; B737 SIC privileges only

Airline Transport Pilot – Airplane Multiengine Land – B737, DC9 type - private pilot privileges – airplane single engine land certificate issued March 9, 2011
Limitations: B737 DC9 circling approach- VMC only; B737 DC9 SIC privileges only

Airline Transport Pilot – Airplane Multiengine Land – B737, DC9 type - private pilot privileges – airplane single engine land certificate issued January 11, 2015
Limitations: English proficient; B737 DC9 circling approach- VMC only; B737 SIC privileges only

2.2.2 The First Officer's Certificates and Ratings at the Time of the Accident

Airline Transport Pilot issued January 11, 2015

Airplane Multiengine Land
DC9, B737
Private Pilot privileges
Airplane Single Engine Land

Limitations: English Proficient; B737 DC9 Circling approaches – VMC only; B737 SIC privileges only

Flight Engineer issued June 18, 2001
Turbojet Powered

FAA Medical Certificate dated July 14, 2014
First Class
Limitations: None

2.2.3 The First Officer's Training and Proficiency Checks Completed

The FO's recent training history based on Delta records:

Date of Hire (Delta)	September 03, 2007
Date of Initial Type Rating on MD88	March 9, 2011
Date of Most Recent Maneuvers Validation	January 11, 2015
Date of Most Recent SPOT Training	January 11, 2015
Date of Most Recent LOE	April 8, 2014
Date of Most Recent Recurrent Ground Training	January 10, 2015
Date of Most Recent Line Check	August 9, 2013

2.2.4 The First Officer's Flight Times

The FO's flight times based on Delta records and pilot statements:

Total flight time:	11,000 hours
Total Pilot-in-Command (PIC) time:	2,000 hours
Total MD88/90 time:	2,938 hours
Flight time last duty period:	3.8 hours
Flight time last 30 days:	64 hours
Flight time last 60 days:	118 hours
Flight time last 90 days:	184 hours
Flight time last 365 days:	671 hours

3.0 Airplane Information

The accident airplane was a twin-engine turbofan Boeing MD88, registration N909DL (serial number 49540). According to Boeing, the MD88 was part of a family of MD80 and MD90 series jetliners originally conceived as a stretched variant of the DC9. The DC9-80, also known as the Super 80, first flew October 18, 1979. Several models of the MD80 series were produced between 1980 and 1999, including the MD81, MD82, MD83, MD87 and MD88. According to Boeing information, 1,191 MD80 series airplanes were produced, of which 150 were MD88's. Boeing data also showed 116 MD90's were produced between 1995 and 2000.

Delta Air Lines operated 117 MD88 and 65 MD90 airplanes at the time of the accident. The accident crew was current and qualified to operate both the MD88 and MD90.

4.0 Weight and Balance

The following weight and balance information was taken from the flight release and ACARS WDR[19] update. Limitations were taken from the Delta MD88/90 Airplane Operation Manual (AOM), Volume 1, dated January 16, 2014.

	Basic Operating Weight (BOW)	84,430
	Passenger Weight	23,727
	Baggage Weight	2,090
	Weight Tolerance (see below)	1,000
	Zero Fuel Weight (ZFW)	111,247
	Maximum Zero Fuel Weight (MZFW)	**122,000**
	Fuel Weight	29,950
	Ramp Weight	141,197
	Maximum Ramp Weight[20]	**161,000**
	Taxi fuel	900
	Takeoff Weight	140,297
	Maximum Takeoff Weight (MTOW)	**160,000**
	Takeoff Center of Gravity (CG)	13.7%[21]
	Planned Fuel Burn	12,066
	Additional fuel burn	800
	Estimated Landing Weight	127,431
	Maximum Landing Weight (MLW)	**139,500**

According to the MD-88 WBM Section 3945.2, Page 2, the OEW included flight crew and bags, flight attendants and bags, galley carts, inserts, and contents, and cabin supplies (pillows, blankets, literature, etc.). Baggage was calculated assuming 30 lb. per bag, unless the bag was designated "heavy," in which case 60 lb. was used. Once calculated, the baggage weights were combined with the actual weight of any freight, and a total was shown for each bin.

According to Delta, "weight tolerance" was an additional 1,000 lb. added to the ZFW. Delta officials described this as an "operational filter" that was used to accommodate additional

[19] Weight data record. According to the Delta FOM, page 5.6.1, the only authorized sources of takeoff data are the Aircraft Weight and Balance System (AWABS), manually produced WDR, or the ODM. AWABS produces two products, the flight plan addendum and the WDR.

[20] The Delta MD88/90 AOM, Volume 1, referred to the maximum ramp weight as "Maximum Taxi Weight (MTW)."

[21] For the takeoff weight of 140,300 lb., the forward CG limit was approximately 6.7% MAC and the aft CG limit was approximately 21.0% MAC, based on the MD-88 Weight and Balance Manual (WBM), Sec 3945.10, page 16.

passengers or cargo without transmitting an additional Weight Data Record (WDR) if the impact on Weight and Balance was negligible to the airplane performance information displayed on the previous WDR. This reduced the need to transmit multiple WDRs to the crews with no change to the V-speeds or stabilizer setting. As a result, crew distractions and unnecessary delays during taxi were reduced. If the change in weight was more than 1,000 lbs., or if the change in airplane CG was more than 0.5 units MAC (forward or aft), a new WDR was sent.

5.0 Airplane Performance

5.1 Landing Performance

5.1.1 Approach Speed

Based on the flight plan estimated time enroute of 1 hour 30 minutes and final takeoff weight figures, the planned landing weight was 128,231 lbs. The flight maneuvered for 10 additional minutes in the vicinity of the destination, burning an approximate additional 800 lbs. of fuel, resulting in an actual landing weight estimated to be 127,431lbs. The FO stated in an interview the crew used the landing TOLD[22] card for 127,500 lbs.[23] The VREF40[24] (40° flap) speed for that weight shown on the card was 131 knots.

According to the Delta MD88/90 Flight Crew Training Manual (FCTM) page 1.18, "Landing," dated January 16, 2014, if the autothrottle is planned to be disconnected prior to landing, the recommended method for approach speed correction for winds is to add ½ of the reported steady headwind component plus the full gust increment to the reference speed. The last wind figure given to the crew by LGA tower before landing was 020° at 10 knots.

The FO stated the crew added 5 knots to VREF to arrive at a final approach bug speed[25] of 136 knots. According to recorded data, the flight's indicated airspeed on final approach was approximately 140 knots and on touchdown was 133 knots.

The Delta MD88/90 FCTM, page 1.19 had the following note:

> *Note: Do not apply wind additives for tailwinds. Set command speed at VREF + 5 knots (autothrottle engaged or disconnected).*

5.1.2 Tailwind Limitation

The captain monitored the wind display during the approach and noted he had a 10 to 11 knot tailwind which changed to a quartering tailwind as they continued.[26] Prior to landing, the tower controller reported the wind as 020 degrees at 10 knots. Based on these reported winds, the

[22] Takeoff and landing data.
[23] See Attachment 4 - Landing TOLD card.
[24] VREF was defined as 1.3 times the stalling speed in the landing configuration. It was the required speed at the 50-foot height above the threshold end of the runway. (Source: Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A, Chapter 10, page 10-32).
[25] Target approach speed.
[26] See Attachment 25 - Wind Display.

tailwind component was 4 knots. According to the Delta MD88/90 AOM, page L.10.1, the maximum takeoff and landing tailwind component was 10 knots, or as permitted by Delta Special Page (Green Page).[27]

According to the Delta MD88 Fleet Captain, Delta provided crosswind training for its pilots, but did not train for tailwinds.[28]

5.1.3 Landing Distance Assessment and Guidance

According to the Delta MD88/90 AOM Volume 1, Supplementary Procedures – Adverse Weather, pages 16.12 to 16.14, dated October 23, 2014, crews should refer to the ODM, Operational Landing Distance tables, prior to landing in the event of landing on a contaminated runway to ensure they had adequate runway length to land on. Under the heading "Guidelines for Contaminated Runways," it stated "When there is contamination on the runway or the braking action is less than good, captains must evaluate crew, aircraft, and environmental conditions in determining the safety of operating their flight."

The Delta MD88/90 AOM further stated that for landing on a contaminated runway, the following guidance should apply:

> • *Do not land with a braking action report of NIL by any air carrier aircraft or airport operator in the landing or rollout portion of the runway.*
> • *Do not land with standing water, slush, or wet snow in excess of one inch (2.5 cm) depth.*
> • *Do not land in dry snow in excess of four inches (10 cm) depth.*
> • *Use maximum landing flap configuration when landing on a contaminated runway.*
> • *Consider using MAX autobrakes for maximum stopping effectiveness.*
> • *Land as early in the touchdown zone as possible.*
> • *Do not assume the last 2,000 feet of the runway will have braking action as good as the touchdown zone.*
> • *Avoid abrupt steering inputs.*
> • *Use maximum allowable symmetrical reverse thrust.*
> • *If side slipping off the runway, select reverse idle and release brakes to return to centerline.*
> • *Aircraft will tend to drift off the runway nose first with forward thrust and tail first with reverse thrust.*
> • *Be aware of the possibility of white out effect from reverse thrust use in dry snow.*

The accident crew stated in interviews they assessed how conditions being reported at LGA would affect the airplane's landing performance using company guidance. They stated they did not intend to land unless braking action "good" was being reported. The FO stated that he calculated their landing distance would be less than 7,000 ft. if the runway condition was good, and 7,200 ft. if the runway condition was fair (similar to medium). The captain stated he

[27] A review of the Delta Green Page for LGA did not specify a different maximum tailwind component.
[28] Email received April 5, 2016.

estimated the landing distance would be about 7,400 ft. if the runway condition was medium, but he knew if he had good braking conditions he would be able to land safely.

5.1.4 Runway Condition/Braking Action Chart

The Delta MD88 Operational Data Manual (ODM) quick reference section provided a chart showing how braking action reported by pilots (PIREP's) should be defined and correlated to runway contaminants, ICAO runway condition codes, Mu[29], and runway Condition Reading (RCR)[30]. The chart was dated February 15, 2015. The definition of good braking action was "braking action is normal for the wheel braking effort applied and directional control is normal." The definition of medium (fair) braking action was "Braking deceleration is noticeably reduced for the wheel braking effort applied or directional control is noticeably reduced."

5.1.5 Calculation Based on Braking Condition Good[31]

According to the Delta ODM "quick reference chart - operational landing distances" page, dated February 12, 2015, the landing distance for an MD88 weighing 127,500 lbs. and configured with 40° of flaps with "good" runway conditions was 6,050 ft. using the maximum autobrake setting, and 5,350 ft. using maximum manual braking. The chart assumed the use of 1.3 EPR reverse thrust, a touchdown speed of VREF40 – 5 knots, 1,500 ft. air distance from threshold to touchdown, and a 15% safety margin.

A chart corrections table on the same page provided additional adjustments for altitude, wind, extra speed, temperature, slope and reverse thrust function. Based on the airport's approximate sea level elevation, the flight's four knot tailwind component, a 7 knot speed adjustment (126 knots planned and 133 knots actual),[32] temperature -3°C, no slope, and both thrust reversers operative, an increment of +520 ft. (-200 ft. for altitude, +600 for tailwind, +420 ft. for speed, -300 ft. for temperature,) resulted in a reference landing distance of 6,570 ft. for maximum autobrake use and 5,870 ft. for maximum manual braking.

The ODM provided an emergency landing distance chart that provided actual landing distances on contaminated runways (excluding the 15% safety margin). The chart stated these figures were to be used only under the captain's emergency authority. For the same conditions as shown above, the actual landing distance shown in the chart for use of maximum autobrake was 5,770 ft. and for maximum manual braking was 5,170 ft.

[29] A measure of friction.
[30] See Attachment 5 - MD88 Runway Condition – Braking Action Chart.
[31] See Attachment 6 - MD88 Landing Distance Chart.
[32] The VREF40 speed was planned for 131 knots. The planned touchdown speed was 126 knots (VREF40-5 per the Delta ODM "quick reference chart"), or 131-5=126. According to recorded data, the airplane touched down at 133 knots, or 7 knots greater than the planned touchdown speed of 126 knots.

5.1.6 Calculation Based on Braking Condition Medium[33]

The ODM landing distance chart showed the landing distance for an MD88 weighing 127,500 lbs. and configured with 40° of flaps with "medium" runway conditions was 7,700 ft. using the maximum autobrake setting, and 7,150 ft. using maximum manual braking. The chart assumed the use of 1.3 EPR reverse thrust, a touchdown speed of VREF40 – 5 kt., 1,500 ft. air distance from threshold to touchdown, and a 15% safety margin.

Applying the same conditions as shown above with an increment of +830 ft. (the table corrections were -300 ft. for altitude, +1000 for tailwind, +630 ft. for speed, -500 ft. for temperature) the reference landing distance was 8,530 ft. for maximum autobrake use and 7,980 ft. for maximum manual braking.

The emergency landing distance chart showed that for a medium runway condition the actual landing distance for use of maximum autobrake was 7,360 ft. (6,700 ft. plus a 660 ft. increment) and for maximum manual braking was 6,910 ft. (6,250 ft. plus a 660 ft. increment).

The length of runway 13 at LGA was 7,003 ft.

5.1.7 Crosswind Guidance

Based on the last reported winds, the crosswind component for the flight at the time of landing was 9 knots. The Delta MD88/90 Operations Manual, L.10.2 stated the following:

> *The Delta MD-88/90 crosswind limit is 30 knots for takeoff or landing, including gusts.*
>
> > *Note: The crosswind component may be further limited by low visibility approaches, contamination, or runway width.*
> >
> > *Note: Refer to SP.16, Guidelines for Contaminated Runways.*

The Delta AOM Volume 1, Supplementary Procedures – Adverse Weather, page 16.13, dated October 23, 2014, stated "On slippery runways, crosswind guidelines are a function of runway surface condition, airplane loading, and proper pilot technique." Guidelines were provided in a table which showed that for the conditions that prevailed at the time of the accident, for a runway with good braking action the recommended landing crosswind component was 30 knots, and for a runway with medium/fair braking action the recommended landing crosswind component was 20 knots. Crosswind guidelines provided in the chart were not considered limitations.[34]

6.0 Airplane Systems

The following information has been taken from the Delta MD88/90 AOM Volume 2.

[33] See Attachment 6 - MD88 Landing Distance Chart.
[34] See Attachment 7 - Crosswind Guidance .

6.1 Thrust Reversers

The accident airplane was an MD88. The MD88 was powered by two Pratt and Whitney JT8D-219 engines, and the MD90 was powered by two International Aero Engines (IAE) V2528-D5 engines. Certain MD90 thrust reverser information is provided here for reference.

On both the MD88 and MD90 the thrust reverse levers were mounted on the throttles, and could only be operated with the throttles at idle. Moving each thrust lever aft actuated the respective thrust reverser and controlled the amount of reverse thrust. As each thrust reverser unlatched, an amber REVERSE UNLOCK light illuminated on the engine display panel. When each reverser was extended, a blue REVERSE THRUST light illuminated on the engine display panel. Once the blue light illuminated, reverse thrust could be increased. [35]

6.1.1 MD88

The thrust reverser on each engine consisted of two deflector doors which formed the aft nacelle fairing when stowed. The reversers were hydraulically powered and intended to be used on the ground only. When extended, the doors directed fan and exhaust gases over and under the nacelle. On the MD88, each throttle was cable connected to its respective engine fuel control unit to regulate engine thrust. Beyond the reverse idle detent, the MD88 did not have a reverse thrust detent to assist the pilot in judging the level of reverse thrust applied.

6.1.2 MD90

The thrust reversers provided reverse thrust from fan air only. Thrust reverser control signals were sent to the electronic engine control (EEC) only when weight was on the main wheels, the throttles were in the reverse position, and the N2 was 7% or more. The thrust reverser system consisted of cold-ducts (C-ducts), translating sleeves, blocker doors and cascades. Blue REVERSE THRUST and amber REVERSE UNLOCK lights similar to the MD88 were provided. In the MD90, ground speed determined reverse thrust capability. If speed was less than 60 knots at reverse thrust initiation, available reverse thrust was 1.07 EPR. When reverse thrust was initiated above 60 knots, the available reverse thrust was 1.3 EPR. A maximum of 1.4 EPR could be obtained in reverse by moving the reverse levers through a detent.

According to the Delta MD88/90 AOM Volume 1, Limitations, engine maximum and minimum limits were displayed as a red radial or arc. The maximum continuous EGT was 580° C No EPR limitation was stated. According to recorded information the highest EGT recorded during the accident landing was 527° C on the left engine and 481° C on the right engine. The highest EPR recorded was 2.07 on the left engine and 1.91 on the right engine.

6.2 Rudder

The rudder provided directional control and was powered by the right hydraulic system. The captain's and FO's rudder pedals were connected by a torque tube forward of the pedals. During powered rudder operation, the rudder control tab was locked hydraulically and rudder pedal

[35] See Attachment 8 - Throttles, Reverse Levers and Indicators.

movement activated the rudder.[36] According to the Delta MD88/90 FCTM, page 6.14, rudder control was effective on landing to approximately 60 knots, and rudder pedal control was sufficient for maintaining directional control during the rollout.

6.3 Spoilers

Each wing had two flight spoilers that were operational during all phases of flight and a ground spoiler that was operational only on the ground. The spoiler system provided the following:

(1) Lateral control augmentation in all modes of flight spoiler operation.
(2) Automatic ground and flight spoiler extension upon touchdown and main wheel spin-up to spoil lift, thereby increasing braking efficiency.
(3) Manual extension of ground and flight spoilers during landing or rejected takeoff.
(4) Selectable extension of flight spoilers to serve as speed brakes.

6.3.1 Spoiler Use During Landing

The spoiler system was armed for automatic operation during landing by pulling up on the speed brake lever until a red armed placard was exposed and the lever latched in the up position[37]. When the system was armed and the throttles were moved towards idle, the spoilers automatically extended after wheel spin-up or after the nose gear actuated ground shift. After landing, all spoilers (flight and ground) were extended to a maximum of 60° to serve as ground spoilers.

If the automatic system was inoperative, all spoilers could be manually extended to full deployment by moving the speedbrake lever up and then aft to the lever stop. Once in this aft position, the lever could be pulled upward once again if desired to engage a lever latch.

On the ground, a SPOILER DEPLOYED message illuminated if any spoiler panel was deployed and the SPD BRK lever was full forward (stowed or armed). A SPOILER/FLAP EXTEND message was illuminated on the ground during manual deployment of spoilers with the flaps extended.

6.4 The Nose Gear, Nosewheel Steering and Wheel Brakes

6.4.1 The Nose Gear and Nosewheel Steering

A ground shift mechanism was operated by the compression and extension of the nose gear strut. When the strut was fully extended, the ground shift mechanism disengaged the rudder pedal nosewheel steering mechanism and hydraulically centered the nosewheel. The ground shift mechanism also actuated ground control relays that established the ground or flight modes of operation.

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[36] See Attachment 9 - Flight Control Locations.
[37] See Attachment 10 - Spoiler – Speedbrake Lever.

Control of nosewheel steering was provided by the rudder pedals and a nose gear steering wheel. The rudder pedals steered through an arc of approximately 17 degrees left or right and the nose gear steering wheel, if used, overrode the rudder pedals and provided an arc of approximately 82 degrees left or right.

6.4.2 Brakes and Anti-Skid

When either set of brake pedals were depressed, hydraulic pressure from both the left and right hydraulic brake system was applied to the main wheel brakes. The anti-skid system reduced hydraulic pressure as necessary to prevent tire skidding. The anti-skid system was electrically controlled. The anti-skid system was operational when the following conditions were met:

- Switch in ARM position
- Gear handle down or alternate gear handle pulled
- Parking brakes released
- Wheel speed greater than 10 knots.

6.4.3 Auto Brake System (ABS)

When armed, the auto brake system automatically applied brakes when the SPD BRK lever moved full aft during takeoff or landing. The ABS landing mode was armed prior to landing, after the landing gear handle was down and flaps were greater than 26 degrees, by selecting MIN, MED, or MAX by the AUTO BRAKE selector and placing the AUTO BRAKE ARM/DISARM switch to ARM.[38] The anti-skid system must be armed and operational as a condition for ABS operation.

ABS landing mode was activated when the spoiler handle was deployed either automatically or manually with throttles retarded and brake pedals released. Automatic braking was delayed after spoiler deployment for approximately 1 second in MAX position and approximately 3 seconds in MIN or MED positions. ABS landing mode was inhibited if the throttles were not retarded towards idle. Disarming could be initiated at any time by manually placing the ARM/DISARM switch into the DISARM position, or by rotating the auto brake selector to OFF, or by depressing either or both brake pedals.

The Delta MD88/90 FCTM, page 6.17, stated the following:

> *Automatic Brakes*
> *Use of the autobrake system is recommend [sic] whenever the runway is limited, when using higher than normal approach speeds, landing on slippery runways, or landing in a crosswind.*
> *For normal operation of the autobrake system select a deceleration setting.*

[38] See Attachment 11 - Auto Brake System Controls.

7.0 Airport Information

LaGuardia Airport was located in the borough of Queens, New York City, and is located 8 miles from midtown Manhattan. The airport borders on Flushing Bay and Bowery Bay. LaGuardia was operated by the Port Authority of New York and New Jersey. There were two main runways, 4-22 and 13-31. Both runways were extended over water to their present length and width in 1967.

7.1 Airport Diagram and Notes

According to the Jeppesen 10-9 and 10-9A pages provided to the crew by Delta, runway 13 was 7003 ft. in length and 150 ft. wide. The runway was grooved and was equipped with high intensity runway lights, centerline lights, approach lights, touchdown zone lighting, runway edge identifier lights, and a precision approach path indicator (PAPI) installed on the left side of the runway. The runway was equipped with runway visual range (RVR) measuring equipment and the usable length of the runway when landing beyond the glideslope intercept point was 6,058 ft.

According to the Jeppesen 10-7 pages provided to the crew by Delta (also known as "green pages"), the northwest 1,000 ft. of runway 13 was constructed on a pier.[39] Autoland was not authorized by Delta for runway 13. A caution note stated:

> *"Cold air circulates under runway piers in cold weather conditions causing precipitation on runway pier and taxiway surfaces to freeze before other surfaces. Braking action may be degraded. No overrun are available."*

7.2 Arrival and Approach Procedure[40]

The accident flight flew the KORRY THREE Arrival and was vectored by ATC to fly the ILS approach to runway 13 (Jeppesen 11-2 page). This approach was a Category I ILS with a decision altitude (DA) of 214 ft. msl, based on 200 ft. height above the touchdown zone. The minimum visibility required was ½ statute mile or an RVR of 2,400 ft. A note stated that a minimum visibility of 1,800 RVR could be used if flight director, autopilot, or heads up display (HUD) was used until reaching the DA.[41]

8.0 Air Traffic Control

8.1 Braking Action Reports

An ATC recording of the LGA tower radio frequency showed that four airplanes landed on runway 13 in the 19 minutes before the accident flight landed. Each flight was provided the most current braking action reports by the tower. The following is a summary of the braking action reports provided by the flights which preceded the accident flight:

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[39] See Attachment 13 – Airport View and Pier Dimensions.
[40] For approach procedures used by the accident crew, see Attachment 12 – Airport Diagram and Approach Procedures.
[41] See Attachment 12 – Airport Diagram and Approach Procedures.

At 1043 United 462, an A320, landed. The crew was recording as saying after landing, “braking action medium at touchdown and its worse down here at rollout. It’s poor down here where we’re coming off the runway at Mike.”

At 1046 United 694, an A320, landed. The crew was recorded as saying after landing, “braking action was good.”

At 1055 Envoy 3647, A CRJ, landed. The crew was recorded as saying after landing, “it was good on the braking action.”

At 1100 Delta 1526, an MD88, landed. The crew did not report braking action to the tower. In statements submitted to the NTSB following the accident, both pilots stated the braking action was good.[42]

The accident flight landed about 1102.

FAA Safety Alert for Operators (SAFO) 06012 Landing Performance Assessments at Time of Arrival (Turbojets), dated August 31, 2006, stated the following in part:

The following braking action reports are widely used in the aviation industry and are furnished by air traffic controllers when available. The definitions provided below are consistent with how these terms are used in this guidance.

Good – More braking capability is available than is used in typical deceleration on a non-limiting runway (i.e., a runway with additional stopping distance available). However, the landing distance will be longer than the certified (unfactored) dry runway landing distance, even with a well executed landing and maximum effort braking.

Fair/Medium – Noticeably degraded braking conditions. Expect and plan for a longer stopping distance such as might be expected on a packed or compacted snow-covered runway.

Poor – Very degraded braking conditions with a potential for hydroplaning. Expect and plan for a significantly longer stopping distance such as might be expected on an ice-covered runway.

Nil – No braking action and poor directional control can be expected.

SAFO 06012 defined “Reliable Braking Action Report” as follows:

For the purpose of this guidance, means a braking action report submitted from a turbojet airplane with landing performance capabilities similar to those of the airplane being operated.

SAFO 0612 further stated the following:

[42] See Attachment 24 - Crew Statements of Preceding Flights.

… because pilot braking action reports are subjective, flightcrews must use sound judgment in using them to predict the stopping capability of their airplane. For example, the pilots of two identical aircraft landing in the same conditions, on the same runway could give different braking action reports. These differing reports could be the result of differences between the specific aircraft, aircraft weight, pilot technique, pilot experience in similar conditions, pilot total experience, and pilot expectations. Also, runway surface conditions can degrade or improve significantly in very short periods of time dependent on precipitation, temperature, usage, and runway treatment and could be significantly different than indicated by the last report. Flightcrews must consider all available information, including runway surface condition reports, braking action reports, and friction measurements.

According to FAA AC 91-79, Runway Overrun Prevention, dated November 6, 2007, when braking action conditions less than Good were encountered, pilots were expected to provide a PIREP. The terms "Good to Medium" and "Medium to Poor" represented an intermediate level of braking action, not a braking action that varied along the runway length. If braking action varies along the runway length, such as the first half of the runway was Medium and the second half was Poor, pilots were to clearly report that in the PIREP (e.g., "first half Medium, last half Poor").

9.0 Organizational and Management Information

9.1 Delta Air Lines

Delta was a major international air carrier headquartered in Atlanta, Georgia. The company served 326 destinations in 59 countries, according to the company's website. As of March 2015, the company operated 722 airplanes and conducted over 5,400 flights daily, including 269 daily departures from LGA. According to company-provided information, the company had 11,709 active pilots, of which 1,014 were MD88/90 captains and 1,036 were MD88/90 FO's.

9.2 Management Organization

Delta's Senior Vice President Flight Operations was responsible for flying operations and training. He was the 14 CFR Part 119 Director of Operations (DO). Reporting to him were a Vice President Flying Operations & Chief Pilot, a Managing Director Flight Training, a Managing Director Technical & Operations Support, and a Managing Director Crew Resources & Schedules. Reporting to the Chief pilot were the Director Flight Standards and Director Line Operations.

The Chief Line Check Pilot (CLCP) MD88 reported to the Director of Flight Standards. The CLCP hired and trained line check pilots (LCP), maintained the operating experience (OE) guide and functional check flight (FCF) program, monitored charter operations for the MD88/90 fleet, evaluated new locations (destinations), published the "Mad Dog Messenger" fleet newsletter and co-authored Flight Crew Bulletins and Electronic Bulletins for the 88/90. He was a member of the TMG (threat management group), and the JTS (joint training standards) group.

The Fleet Captain MD88 reported to the Managing Director Flight Training. The Fleet Captain oversaw the simulator training as a primary function and also oversaw curriculum and manual revisions for the MD88/90 fleet.

10.0 Company Procedural Guidance

10.1 Landing on Slippery Runways

The Delta MD88/90 AOM, Volume 1, page SP.16.11 stated "when there is contamination on the runway or the braking action is less than good, captains must evaluate crew, aircraft, and environmental conditions in determining the safety of operating their flight."

The Delta MD88/90 FCTM, chapter 6, "Slippery Runway Landing Performance," page 6.15, dated January 16, 2014, stated the following: [43]

> *"When landing on slippery runways contaminated with ice, snow, slush, or standing water, the reported braking action must be considered. Stopping distances for the various autobrake settings and for non-normal configurations are provided in the ODM. Pilots should use extreme caution to ensure adequate runway length is available when poor braking action is reported.*
>
> *Note: Consider delaying thrust reverser deployment until nose wheel touchdown, so that directional control is not affected by asymmetric deployment.*
>
> *Slippery/contaminated runway performance data is based on an assumption of uniform conditions over the entire runway. This means a uniform depth for slush/standing water for a contaminated runway or a fixed braking coefficient for a slippery runway. The data cannot cover all possible slippery/contaminated runway combinations and does not consider factors such as rubber deposits or heavily painted surfaces near the end of most runways.*
>
> *Refer to the Vol. 1, SP.16 and the AM, OPS-4WX.3.*
>
> ***CAUTION: Reverse thrust above 1.3 EPR may blank the rudder and degrade directional control effectiveness. However, as long as the aircraft is aligned with runway track, reverse thrust may be used as necessary (up to maximum), to stop the aircraft. Do not attempt to maintain directional control by using asymmetric reverse thrust."***

The Delta MD88/90 FCTM further states on page 6.16 and 6.17:

> *"Hydroplaning may cause delayed Auto Spoiler deployment. Be prepared to quickly manually deploy the spoilers. Simultaneously apply brakes and reverse thrust smoothly and symmetrically, as appropriate to the braking action and runway length available to ensure a safe stop. On wet, contaminated, or slippery runways, immediately after nose*

[43] See Attachment 14 - Slippery Runway Landing Performance.

gear touchdown, maximize anti-skid braking operation by applying full brake pressure smoothly and symmetrically while applying reverse thrust to the idle reverse detent. After reverse thrust symmetry is verified, gradually increase reverse thrust as required. Reverse thrust should be applied smoothly and symmetrically to 1.3 EPR as soon as possible since the reverse thrust effectiveness is greatest at higher speeds. Full brake pressure, and reverse thrust, should be maintained until a safe stop is assured. If auto brakes are used, consider selecting the MAX setting."

"The use of reverse thrust may cause a visibility problem from blowing snow forward as ground speed decreases. Take action as appropriate for braking effectiveness and runway length available. Avoid rapid return to forward thrust when engine RPM is high. Resultant forward thrust may be high enough to cause airplane to accelerate. Avoid large abrupt steering inputs. Maintain directional control primarily with rudder pedals. Use differential braking as needed. Be alert for drift toward downwind side of the runway.

The rudder required in strong crosswinds may cause the nose gear to turn to an angle which could induce skidding. Therefore, it may be necessary to hold the nose gear steering wheel centered while controlling steering with rudder and brakes to maintain tracking."

If a skid develops, especially in crosswind conditions, reverse thrust will increase the sideward movement of the airplane. In this case, release brake pressure and reduce reverse thrust to reverse idle, and if necessary, to forward idle. Apply rudder as necessary to realign the airplane with the runway and reapply braking and reversing to complete the landing roll. It is not necessary to immediately correct to runway centerline as this may delay deceleration efforts and aggravate skid conditions. Use as much runway as necessary to slow the airplane. Do not attempt to turn off a slippery runway until speed is reduced sufficiently to turn without skidding. Consider that braking effectiveness in the last 2,000 feet of the runway may be further reduced by painted surfaces and by accumulation of fuel, oil, and rubber. Consider leaving engines in idle reverse until ability to stop, or clear the runway, is assured."

10.2 Wheel Braking

According to the Delta MD88/90 FCTM, page 6.17, use of the autobrake system was recommend whenever the runway was limited, when using higher than normal approach speeds, landing on slippery runways, or landing in a crosswind. Pilots were directed to use the autobrake system to select a deceleration setting. MAX (maximum) autobrakes should be used when minimum stopping distance was required, e.g., cluttered, snow covered, icy, or wet ungrooved runways. In the MAX position, the autobrake system provided a one second delay after spoiler deployment until brake application. MAX autobrakes did not use a deceleration rate, but applied the brakes to the antiskid limit. Deceleration rate was less than that produced by full manual braking. The FCTM contained the following notes:

Note: The use of autobrakes will apply immediate and symmetric braking. If stopping distance is critical, consider using max autobrakes for the touchdown and quickly transitioning to max manual brakes.

Note: Do not delay lowering the nose gear to the runway after landing with MAX selected.

10.3 Reverse Thrust Operation

The Delta MD88/90 FCTM, chapter 6, "Reverse Thrust Operation," page 6.22, dated January 16, 2014[44], stated the following:

> *"After main gear touchdown and once nose lowering has commenced thrust reversers should be deployed to reverse idle detent. Upon nosewheel touchdown and when the ENG REVERSE UNLOCK and ENG REVERSE THRUST lights illuminate increase reverse thrust as required. The PM should monitor engine operating limits and call out any engine operational limits being approached or exceeded, any thrust reverser failure, or any other abnormalities. Maintain reverse thrust as required, up to maximum, until 80 knots.*
> ***Note:** (88) Normal dry runway reverse thrust minimum is 1.3 EPR, target 1.6 EPR.*
> ***Note:** (90) Normal reverse thrust target is 1.3 EPR."*

The Delta MD88/90 FCTM, "Factors Affecting Landing Distance," page 6.14 stated the following:

> *Reverse thrust and spoiler drag are most effective during the high-speed portion of the landing. Deploy the speedbrake lever and activate reverse thrust with as little time delay as possible.*

The Delta MD88/90 FCTM, "Reverse Thrust and Crosswind (All Engines) page 6.25 stated the following:[45]

> *"As the aircraft starts to weathervane into the wind, the reverse thrust side force component adds to the crosswind component and drifts the aircraft to the downwind side of the runway. Also, high braking forces reduce the capability of the tires to corner. To correct back to the centerline, release the brakes and reduce reverse thrust to reverse idle. Releasing the brakes increases the tire-cornering capability and contributes to maintaining or regaining directional control. Setting reverse idle reduces the reverse thrust side force component without the requirement to go through a full reverser actuation cycle. Use rudder pedal steering and differential braking as required to prevent over correcting past the runway centerline. When directional control is regained and the aircraft is correcting toward the runway centerline, apply maximum braking and symmetrical reverse thrust to stop the aircraft.*
>
> ***Note:** Use of this technique increases the required landing distance."*

[44] See Attachment 15 - Reverse Thrust Operation.
[45] See Attachment 16 - Reverse Thrust and Crosswind.

10.4 Required Callouts After Landing

The Delta MD88/90 AOM Volume 1 addressed standard callouts in the normal procedures section. It stated on page NP 12.6 the following standard callouts should be made after landing:

Condition	Crew Member	Callout
Verify spoilers are up	PM	"Spoilers Up"
If spoilers are not up	PM	"No Spoilers"
At 80 knots	PM	"80 knots"

The Delta MD88/90 FCTM stated that the PM should call out any engine operational limits being approached or exceeded, any thrust reverser failure, or any other abnormalities. The Delta MD88/90 AOM did not require a specific callout from either crewmember if reverse thrust power exceeded 1.3 EPR.

10.5 Directional Control During Landing Roll

The normal landing roll procedure in the Delta MD88/90 AOM, Volume 1, page NP.20.76 stated "after main gear touchdown and once nose lowering had commenced thrust reversers may be deployed to reverse idle detent. Upon nosewheel touchdown, normal reverser should be used."

The Delta MD88/90 FCTM, page 6.14, stated the following:

> *If the nose wheels are not promptly lowered to the runway, braking and steering capabilities are significantly degraded and no drag benefit is gained. Rudder control is effective to approximately 60 knots. Rudder pedal steering is sufficient for maintaining directional control during the rollout. Do not use the nose wheel steering wheel until reaching taxi speed. In a crosswind, displace the control wheel into the wind to maintain wings level which aids directional control. Perform the landing roll procedure immediately after touchdown. Any delay markedly increases the stopping distance.*
>
> *Stopping distance varies with wind conditions and any deviation from recommended approach speeds.*

10.6 Evacuation

The Delta Flight Operations Manual (FOM), Chapter 10, Emergency Operations, pages 10.1.4 through 10.1.6, stated if an evacuation was required, to do the following:

> *"After a thorough evaluation, if an emergency evacuation is required:*
>
> *• Make the following pre-evacuation announcement when directed by the Emergency Evacuation Checklist*[46]*, to instruct the cabin crew to prepare for evacuation.*

[46] See Attachment 17 - Evacuation Checklist.

“EASY VICTOR, EASY VICTOR, EASY VICTOR.”

Note: *The “Easy Victor” command should be followed up by either the evacuation announcement or the following announcement canceling the evacuation:*
“This is the captain. Remain seated with your seat belt fastened.”

• Make the following announcement when directed by the Emergency Evacuation Checklist
“This is the captain. Evacuate, evacuate.”
• If an engine fire or other condition makes certain exits unusable, state the direction of egress. State these special instructions before using the word “evacuate” to help ensure they are heard and understood.
i.e., “This is the captain. Using the right exits only, evacuate, evacuate.”

Note: *B717 and MD88/90: “This is the captain. Right side, right side, tail cone, tail cone, evacuate, evacuate.”*

Note: *The first officer should ensure the forward exits are open, exit the aircraft from a forward exit and assist in the evacuation from outside the aircraft. Refer to QRH for specific procedures.*

• Remove all passengers beyond the fire equipment and, if possible, off any paved surface, out of range of possible fire or explosion.
• The captain, or designee, will ensure that passengers remain in the gathering areas until transportation is arranged to remove the passengers from the site.
• Do not allow passengers to return to the aircraft or depart the site until directed.

Note: *The captain will attempt to ascertain the location and status of all crewmembers and ensure that the appropriate checklist (post-emergency, post-incident, or post-accident) is accomplished”*

The Delta MD88/90 FCTM, Chapter 8, “Non-Normal Operations,” pages 8-14 to 8-16 provided guidance on evacuations, and stated:

“For unplanned evacuations, the captain needs to analyze the situation carefully before initiating an evacuation order. Quick actions in a calm and methodical manner improve the chances of a successful evacuation.

All available sources of information should be used to determine the safest course of action including reports from the cabin crew, other aircraft, and air traffic control. The captain must then determine the best means of evacuation by carefully considering all factors. These include, but are not limited to:

• the urgency of the situation, including the possibility of significant injury or loss of life if a significant delay occurs

• the type of threat to the aircraft, including structural damage, fire, reported bomb on board, etc.
• the possibility of fire spreading rapidly from spilled fuel or other flammable materials
• the extent of damage to the aircraft
• the possibility of passenger injury during an emergency evacuation using the escape slides.

If in doubt, the crew should consider an emergency evacuation using the escape slides.

If there is a need to deplane passengers, but circumstances are not urgent and the captain determines that the Evacuation NNC is not needed, the normal shutdown procedure should be completed before deplaning the passengers."

Captain and FO post-landing duties were summarized in a chart in the Delta MD88/90 FCTM.[47]

10.7 Company MD88/90 Bulletins

Delta's fleet and pilot standards management team published an MD88/90 fleet newsletter periodically. Its purpose was to provide additional detail about operational policies and procedures and aircraft technical information for line pilots. Prior to the accident, the bulletins addressed landing operations and thrust reverser use on several occasions.

The April 2012 newsletter addressed runway excursions and contaminated runways. With regard to use of reverse when landing on contaminated runways, it stated:

"Initially use idle reverse to avoid asymmetrical reversing. Additional reverse thrust can be used as necessary while maintaining directional control. Remember, reversing with more than 1.3 EPR may blank the rudder and degrade directional control."

The April 2014 newsletter addressed use of a newly revised operational landing distance chart. Another bulletin about landing operations published in April 2014 emphasized proper use of reverse thrust. A bulletin published in November 2014 discussed use of wheel brakes and reversers, and stated:

"Reversers: *Line Check data shows that many pilots accept reverser settings far below the target. Remember on the MD-88, for a dry runway the MINIMUM is 1.3 EPR and the TARGET is 1.6. On a runway that is not dry, 1.3 EPR is the target. On the MD-90 the target is always 1.3 (to the detent).*

MD-88 Reversers: *On the 88 strive to attain 1.6 EPR (N1's at 1 o'clock) and be patient; it will decelerate. Give it a few seconds before jumping on the brakes. 1.6 is easiest to attain if you "walk" the reverse levers 2 knob widths from idle. As the engines wind up all it takes is a bump fore or aft as you see which side is increasing fast or slow. Don't*

[47] See Attachment 18 - Captain and FO Duties – Evacuation.

> *keep pulling, let it have time to react. Practice this on the long runways so that you can reliably get there on the short runways."*

The February 2015 bulletin emphasized the procedural guidance regarding reverse thrust:

> *"Line check data indicates that many of us can tighten up our reverser operations. Remember that Volume 1 NP.20.76 tells us, 'After main gear touchdown and once nose lowering has commenced thrust reversers may be deployed to reverse idle detent. Upon nosewheel touchdown, normal reverse should be used'. So, wait until the nosewheel gets to the runway to go past idle reverse. Remember when flying the MD-88 that on a dry runway minimum EPR is 1.3; target EPR is 1.6. On a runway that is not dry - 1.3 EPR is the target."*

10.8 Company MD88 Training on Contaminated Runway Landings

In the three years prior to the accident Delta had conducted training on contaminated runway operation and use of reverse thrust in MD88/90 recurrent training.

In the recurrent training cycle from July 2012 to March 2013, SPOT training included a simulator scenario with an un-grooved contaminated runway operation. The following guidance from training module CG 603 was provided:

> *"Additional reverse thrust should be applied while watching carefully for signs of directional control problems, Remember, applying reverse thrust above 1.3 EPR will potentially blank rudder effectiveness and degrade directional control.*
>
> *If directional control is compromised, reduce reverse thrust to idle reverse and hold forward stick pressure to regain centerline track."*

The scenario, which was based on a directional control incident which took place in Cancun, required the pilot to land in a 10 knot crosswind in heavy rain.

In the recurrent training cycle from April 2013 to December 2013 (module 604), SPOT training addressed takeoffs on contaminated runways. One scenario included the same contaminated runway landing conditions as done in the previous cycle.

In the recurrent training cycle from January 2014 to September 2014 (module 601), training addressed proper calculation of landing distance using ODM charts.

The accident pilots' training records indicated they had received those recurrent training sessions.

The Delta MD88/90 fleet captain, who oversaw simulator training for the fleet, stated in an interview the key to getting directional control in a rudder blanking situation was to neutralize reverse thrust to idle and get control back. He said on the MD88, targeting 1.6 EPR on a dry runway and 1.3 EPR on a contaminated runway was an emphasis item in their briefings and in the Delta MD88/90 FCTM revision highlights. He said to address the lack of a 1.3 EPR detent on the MD88 reverse levers, they trained pilots to wait until the nose was trending down and to avoid yanking the throttles out. He said they expected pilots to pull the reverse thrust levers uniformly while watching the N1 RPM's (revolutions per minute) in case they split.

10.9 Special Winter Operations Airports (SWOA)

Delta addressed "Special Winter Operations Airports" (SWOA) in the Delta Airway Manual Weather section, pages OPS-4WX 2.4 to 2.5. Certain airports were designated as SWOA airports due to several factors including climate and snowfall, Delta historical incidents, airport infrastructure, airport runway friction measuring equipment, runway length, and airport elevation. Airports designated as SWOA included additional restrictions that only applied when snow, ice, or slush existed on the runway of intended takeoff or landing, or if freezing precipitation was falling and accumulating on the runway.

In an interview, the Delta manager of flight safety programs stated there were about 36 airports on the SWOA list. He stated LGA was not on the SWOA airport list.

10.10 Go-around Guidance

The Delta FOM, page 3.4.10, stated, in part:

> *Missed Approach, Go-Around, Rejected Landing*
> *The PF, PM, and relief pilot(s) are responsible for monitoring the approach. If any flight crewmember recognizes conditions outside the stabilized approach criteria a "Go-Around" must be called. If a "Go-Around" is called by any flight crewmember, the "Go-Around" must be honored.*[48]
>
> *Refer to specific aircraft FCTM, QRH, and Volume 1 for Missed Approach/Go-Around/ Rejected Landing procedure.*

11.0 Boeing Guidance

Boeing issued an All Operators Letter to MD80 Operators on February 15, 1996 that addressed MD80 handling characteristics when landing on wet or slippery runways[49]. It stated the use of reverse thrust affects the aerodynamic efficiency of the rudder. Thrust reverser buckets were canted slightly to prevent foreign object damage (FOD), and that canting resulted in disruption of airflow across the rudder at thrust levels above approximately 1.3 EPR. The letter stated reverse thrust levels above 1.3 EPR decrease rudder and stabilizer effectiveness until reaching 1.6 EPR, at which point the rudder and stabilizer provide little or no directional control.

Boeing issued Service Bulletin MD80-78-068 on May 29, 1996 which addressed MD80 thrust reversers. Specifically, it provided for a new improved thrust reverser cam support assembly to provide the flight crew with a physical indication of when the thrust levers were at 1.3 EPR.

[48] For Delta stabilized approach criteria, see Attachment 26 - Stabilized Approach.
[49] See Attachment 19 - Boeing All Operators Letter AOL-9-058.

However, the bulletin was rescinded by Service Bulletin MD80-78-070 on May 29, 1997 due to reports of excessive EPR splits between engines with the new cam installed.[50]

In addition, Boeing issued a Flight Operations Bulletin applicable to all MD80 Aircraft on November 5, 2002 that addressed reverse thrust EPR control[51]. It stated 1.3 EPR should be the maximum reverse thrust power under wet or slippery runway conditions.

The Boeing MD80 Flight Crew Operations Manual (FCOM), Volume II – Operating Procedures, revision 10, dated May 15, 2014, stated in a caution:

> *"Caution: On wet slippery or contaminated runways, stopping distance is based on maximum manual anti-skid braking, with application of no greater than 1.3 EPR reverse thrust."*

The Boeing MD80 FCOM did not require a specific callout from either crewmember if reverse thrust power exceeded 1.3 EPR.

12.0 ASRS Reports

An Aviation Safety Reporting System (ASRS) search request addressing MD80 series thrust reverser related landing directional control events found 11 events between 1995 and 2014[52]. Of the 11 events, 9 involved gusty winds or crosswinds, 6 involved low visibility approaches, and 9 involved snow, rain or contaminated runways.

13.0 Selected Previous MD80 Series Directional Control Accidents and Incidents

13.1 Major Accidents

13.1.1 Yuma, AZ

A McDonnell Douglas DC-9-80 test flight departed the runway at Yuma International Airport (YUM) on June 19, 1980. The National Transportation Safety Board determined the probable cause of the accident was the inadequate procedure established for the certification test flight and the pilot's mismanagement of thrust following the initial loss of directional control.[53]

The purpose of the flight was to show that the airplane could be controlled adequately and landed safely with a complete failure of its hydraulic systems. Test conditions called for the rudder hydraulic boost, antiskid and nosewheel steering systems to be turned off. The pilot deployed the thrust reversers and applied reverse thrust before the nosewheel touched down. The airplane began to yaw, continued to yaw after the nosewheel touched down, then ground looped to the right, and slid off the right side of the runway. After the airplane left the pavement, the left main gear collapsed and the right main gear and the nose gear separated from the airplane. The runway was dry and there was a moderate crosswind component of 70 degrees at 7 knots.

[50] See Attachment 20 - MD80 Service Bulletins MD80-78-068 and -070.
[51] See Attachment 21 - Boeing Flight Operations Bulletin MD-80-02-03.
[52] See Attachment 22 - ASRS Thrust Reverser Related Loss of Directional Control Events.
[53] See NTSB-AAR-81-16.

During the investigation test maneuvers were conducted to determine rudder effectiveness under varying levels of forward and reverse thrust. According to the report, the flight test data showed that at 1.6 EPR symmetric reverse thrust and at 109 knots, the powered rudder control effectiveness was zero.

The NTSB issued 11 recommendations to the FAA as a result of the accident (A-81-104 through -112, and -122 and -123). Three of those recommendations, A-81-104, A-81-105, and A81-106, are cited here:

A-81-104:

> *"The NTSB recommends that the federal aviation administration: incorporate the following information into the DC-9-80 aircraft flight manual under the abnormal hydraulics-out landing section and the normal landings on wet/slippery runways section: the maximum rudder effectiveness available is substantially reduced during reverse thrust operation as follows:*

Engine Thrust Setting	*Maximum Rudder Effectiveness Available (percent)*/*
forward idle	*100*
reverse idle	*65*
1.3 EPR (reverse)	*25*
1.6 EPR (reverse)	*minimal*

> **/rudder effectiveness also decreases with decreasing airspeed.*
>
> *When reverse thrust levels above reverse idle are used, carefully monitor and maintain symmetric reverse thrust to avoid adverse yawing moments."* (A-81-104)

The status of recommendation A-81-104 is "Closed – acceptable action."

A-81-105:

> *"The NTSB recommends that the federal aviation administration: incorporate the following information into the DC-9-80 training manuals and training programs under the flight control and landing sections: when thrust reversers (located just forward of the vertical stabilizer) are used during landing rollout, the exhaust gases from the engines are deflected by the thrust reverser buckets in such a manner that the free stream airflow over the vertical stabilizer and rudder is blocked, reducing the effectiveness of these surfaces. At a nominal airspeed of 100 kt., the reduction in rudder effectiveness with increasing symmetric reverse thrust levels is shown below.*

Engine Thrust	*Maximum Rudder Effectiveness*

Setting	*Available (percent)*/*
forward idle	*100*
reverse idle	*65*
1.3 EPR (reverse)	*25*
1.6 EPR (reverse)	*minimal*

**/rudder effectiveness also decreases with decreasing airspeed.*

When reverse thrust levels above reverse idle are used, carefully monitor and maintain symmetric reverse thrust to avoid adverse yawing moments."

On a dry runway, directional control is easily maintained by differential antiskid braking and nosewheel steering. However, under adverse conditions such as a slippery runway with rain, snow, or ice, when crosswinds reduce the braking effectiveness of the gear on the upwind wing, or when a high-speed landing is made with both hydraulics systems out (i.e., flaps/slats retracted, ground spoilers, rudder hydraulic boost, nosewheel steering all rendered inoperative, and brake antiskid systems limited by hydraulic accumulator pressure), the vertical stabilizer and rudder will be the primary source of directional stability and control during the high speed portion of the landing rollout. Under these conditions, it is important to make allowance for the adverse effects of reverse thrust on the effectiveness of the vertical stabilizer and rudder. The cockpit thrust reverser levers in the DC-9-80 are more sensitive (i.e., command increased amounts of thrust per degree of movement) than previous DC-9 models because of higher sensitivity of the cockpit thrust reverser levers make selection of symmetric reverse thrust more difficult than on previous models; therefore, careful attention should be given to selecting and maintaining symmetric reverse thrust levels to avoid adverse yawing moments." (A-81-105)

The status of recommendation A-81-105 is "Closed – acceptable alternate action."

A81-106:

The NTSB recommends that the federal aviation administration: require that dc-9-80 landing-approved simulators incorporate actual aircraft characteristics including the decrease in vertical stabilizer and rudder control effectiveness as a function of engine reverse thrust levels. The flight test data used should be taken from McDonnell Douglas report MDC-J9005. Figure 14, yawing acceleration due to maximum rudder, power on, and figure 15, yawing acceleration due to maximum rudder, manual, should be used for symmetric reverser configurations for thrust values from forward idle to 1.3 EPR reverse. Data similar to that in figure 71, effect of reverse thrust on directional control, should be derived and used for all speeds and symmetric reverse thrust settings. Control effectiveness from a symmetric 1.3 EPR to a symmetric 1.6 EPR should decrease to zero. For asymmetric reverse thrust conditions, the data in figure 20, controllability with asymmetric reverse thrust, should be used.(A-81-106)[54]

[54] See Attachment 23 - Flight Test Figures from MDC-J9005.

The status of recommendation A-81-106 is "Closed – unacceptable action."

13.1.2 Little Rock, AR

An American Airlines MD82 departed the runway at Little Rock National Airport (LIT) on June 11, 1999. The National Transportation Safety Board determined the probable causes of the accident were the flight crew's failure to discontinue the approach when severe thunderstorms and their associated hazards to flight operations had moved into the airport area and the crew's failure to ensure that the spoilers had extended after touchdown. Contributing to the accident were the flight crew's (1) impaired performance resulting from fatigue and the situational stress associated with the intent to land under the circumstances, (2) continuation of the approach to a landing when the company's maximum crosswind component was exceeded, and (3) use of reverse thrust greater than 1.3 engine pressure ratio after landing.[55]

Regarding reverse thrust use, the NTSB found the use of reverse thrust at levels greater than 1.3 engine pressure ratio significantly reduced the effectiveness of the airplane's rudder and vertical stabilizer and resulted in further directional control problems on the runway.

As a result of the investigation, recommendations A-01-51, A-01-52, and A-01-53 related to reverse thrust were issued to the FAA by the NTSB:

> *"Issue a flight standards information bulletin that requires the use of 1.3 engine pressure ratio as the maximum reverse thrust power for MD-80 series airplanes under wet or slippery runway conditions, except in an emergency in which directional control can be sacrificed for decreased stopping distance."* (A-01-51)
>
> *"Require principal operations inspectors of all operators of MD-80 series airplanes to review and determine that these operators' flight manuals and training programs contain information on the decrease in rudder effectiveness when reverse thrust power in excess of 1.3 engine pressure ratio is applied."* (A-01-52)
>
> *"Require all operators of MD-80 series airplanes to require a callout if reverse thrust power exceeds the operators' specific engine pressure ratio settings."* (A-01-53)

These recommendations were all closed with acceptable action.

13.2 Delta MD88 Incidents

13.2.1 St. Louis

A Delta MD88 experienced a runway excursion at Saint Louis International Airport (STL) on March 26, 2011. According to a company investigation, the flight landed on a contaminated runway in heavy snow in a crosswind. The crosswind component was 60 degrees at 10 knots gusting to 15 knots; the runway visibility was 1800 RVR; and the runway condition was fair. The report stated the crew's use of reverse thrust was asymmetric and greater than 1.3 EPR. The

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[55] See NTSB-AAR-01/02.

left thrust reverser was consistently lower than the right; the left EPR reached a maximum of 1.38 and the right thrust reverser reached a maximum of 1.45. The report stated the captain input full right rudder but the airplane continued to move left. The left main landing gear departed the left side of the runway but the crew was able to return the airplane to the runway during the rollout.

13.2.2 Cancun

A Delta MD88 experienced a runway excursion at Cancun International Airport (CUN) on January 14, 2012. According to a company investigation, the flight landed on a contaminated runway in heavy rain. The tower reported calm winds but there was convective activity. Actual winds were not recorded. The runway visibility was ½ statute mile; and the runway condition was reported medium (fair) by the previous landing flight. The report stated the crew's use of reverse thrust was asymmetric and greater than 1.3 EPR; the left EPR reached a maximum of 1.61 and the right thrust reverser reached a maximum of 2.00. The airplane departed the right side of the runway but maneuvered back on to the runway. The engines flamed out and there was significant debris on the fuselage belly, in both landing gear, and in both engine inlets.

14.0 Other Related NTSB Recommendations

On December 22, 2009, about 2222 eastern standard time, American Airlines flight 331, a Boeing 737-800, N977AN, ran off the departure end of runway 12 after landing at Norman Manley International Airport (KIN) Kingston, Jamaica. The aircraft landed approximately 4,000 feet down the 8,911-foot-long, wet runway with a 14-knot tailwind component and was unable to stop on the remaining runway length. After running off the runway end, it went through a fence, across a road, and came to a stop on the sand dunes and rocks above the waterline of the Caribbean Sea adjacent to the road. No fatalities or post-crash fire occurred. Eighty-five of the 154 occupants (148 passengers, 4 flight attendants, and 2 pilots) received injuries ranging from minor to serious. The airplane was substantially damaged. Instrument meteorological conditions and heavy rains prevailed at the time of the accident flight, which originated at Miami, Florida, on an instrument flight rules flight plan.[56]

In a December 7, 2011 letter to the FAA, the NTSB concluded that providing pilots training in tailwind landings would improve pilots' preparation in mitigating the risk of runway overruns while landing in tailwind conditions. The NTSB recommended that the Federal Aviation Administration (FAA) require principal operations inspectors (POI) review flight crew training programs and manuals to ensure training in tailwind landings was (1) provided during initial and recurrent simulator training; (2) to the extent possible, conducted at the maximum tailwind component certified for the aircraft on which pilots are being trained; and (3) conducted with an emphasis on the importance of landing within the touchdown zone, being prepared to execute a go-around, with either pilot calling for it if at any point landing within the touchdown zone becomes unfeasible, and the related benefits of using maximum flap extension in tailwind conditions. (A-11-92) The current status of A-11-92 is "Open-Acceptable Response."

[56] The Jamaican Civil Aviation Authority conducted the investigation of this accident. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the NTSB participated in the investigation, representing the State of the Operator, as well as Manufacture and Design.

The NTSB also concluded that because the dynamics of a tailwind approach and landing, particularly on wet or contaminated runways, expose flight crews to additional risks and challenges, they should be provided current and comprehensive guidance regarding the risks associated with tailwind landings and made aware of the reduced margins of safety during tailwind landing operations. The NTSB recommended that the FAA revise AC 91-79 "Runway Overrun Prevention" to include a discussion of the risks associated with tailwind landings, including tailwind landings on wet or contaminated runways as related to runway overrun prevention. (A-11-93) The current status of A-11-93 is "Closed-Acceptable Action."

Once AC 91-79 had been revised, the NTSB recommended that the FAA require POIs to review airline training programs and manuals to ensure they incorporate the revised guidelines concerning tailwind landings. (A-11-94) The current status of A-11-94 is "Open-Acceptable Response."

F. ATTACHMENTS

Attachment 1 - Interview Summaries
Attachment 2 - Flight Release, NOTAM's, Weather Forecast
Attachment 3 - Enroute ACARS Communication
Attachment 4 - Landing TOLD Card
Attachment 5 - MD88 Runway Condition – Braking Action Chart
Attachment 6 - MD88 Landing Distance Chart
Attachment 7 - Crosswind Guidance
Attachment 8 - Throttles, Reverse Levers and Indicators
Attachment 9 - Flight Control Location
Attachment 10 - Spoiler - Speed Brake Lever
Attachment 11 - Auto Brake System Controls
Attachment 12 - Airport Diagram and Approach Procedures
Attachment 13 - Airport View and Pier Dimensions
Attachment 14 - Slippery Runway Landing Performance
Attachment 15 - Reverse Thrust Operation
Attachment 16 - Reverse Thrust and Crosswind
Attachment 17 - Evacuation Checklist
Attachment 18 - Captain and FO Duties - Evacuation
Attachment 19 - Boeing All Operators Letter AOL-9-058
Attachment 20 - MD80 Service Bulletins MD80-78-068 and -070
Attachment 21 - Boeing Flight Operations Bulletin MD-80-02-03
Attachment 22 - ASRS Thrust Reverser Related Loss of Directional Control Events
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Attachment 24 - Crew Statements of Preceding Flights
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Captain David Lawrence
NTSB Operations Group Chairman

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