Submission of the
Air Line Pilots Association, International
to the
National Transportation Safety Board
Regarding the Accident Involving

Delta Air Lines 1086

MD-88

DCA15FA085

New York, NY

March 5, 2015

Table of Contents

Table of Figures

Acronyms/Definitions

AA	American Airlines
AC	Advisory Circular
ACARS	Aircraft Communications Addressing and Reporting System
ACM	Airport Certification Manual
AGL	Above Ground Level
AIM	Aeronautical Information Manual
AOL	All Operator Letter
AOM	Aircraft Operating Manual
APU	Auxiliary Power Unit
ARC	Aviation Rulemaking Committee
ARFF	Aircraft Rescue and Firefighting
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATCT	Air Traffic Control Tower
ATIS	Automatic Terminal Information Service
ATL	Hartsfield-Jackson Atlanta International Airport
CAWS	Central Aural Warning Systems
CFME	Continuous Friction Measuring Equipment
CFR	Code of Federal Regulations
CRJ	Canadair Regional Jet
CVR	Cockpit Voice Recorder
DAB	Daytona Beach International Airport
DAL	Delta Air Lines
EPR	Engine Pressure Ratio

EST	Eastern Standard Time
FAA	Federal Aviation Administration
FCTM	Flight Crew Training Manual
FDR	Flight Data Recorder
FO	First Officer
G	Acceleration of Gravity
Hz	Hertz
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
LGA	LaGuardia Airport
LOA	Letter of Agreement
MAT	Marine Air Terminal
METAR	Meteorological Aerodrome Report
N1	Rotational Speed of Low Pressure Compressor
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board
NWS	National Weather Service
ODM	Operational Data Manual
PA	Public Address
PF	Pilot Flying
PIREP	Pilot Report
PM	Pilot Monitoring
PSEU	Proximity Switch Electronics Unit

QAR	Quick Access Recorder
RCAM	Runway Condition Assessment Matrix
SMR	Surface Movement Radar
SPOT	Special Purpose Operational Training
SWOA	Special Winter Operations Airport
TALPA	Takeoff and Landing Performance Assessment
UAL	United Airlines
UTC	Coordinated Universal Time
V_{ref}	Reference Speed
WOW	Weight on Wheels

Executive Summary

On March 5, 2015, at about 1102 Eastern Standard Time (EST)[1], a Boeing MD-88, N909DL, operated as Delta Air Lines (DAL) Flight 1086, landed on Runway 13 at LaGuardia Airport (LGA), New York, N.Y., exited the left side of the runway, contacted the airport perimeter fence, and came to rest with the aircraft nose on an embankment overhanging 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 aircraft 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.

The following analysis outlines the event and “findings” leading up to the accident and provides recommendations to prevent similar events from occurring in the future. The analysis of this event identifies several contributing factors, including flightcrew training, guidance provided in the manuals, and airport-related issues. This accident cannot be reduced to one specific cause; rather, a chain of events led to this accident.

During the flight from ATL to LGA, the flight crew was diligent in obtaining information on the conditions they would encounter upon arrival at LGA. Several times the crew requested braking action reports and discussed issues with landing on a contaminated runway. The crew completed an extensive approach briefing and selected the most conservative configuration for landing on a contaminated runway. When the flight crew had the runway in sight, it was not what they expected. Both pilots had a picture in their mind that they would see a black runway, not one completely covered in snow.

The captain adjusted his aim point to land the aircraft on the runway sooner than briefed, in accordance with the Delta manuals. The aircraft touched down on the pier that had had been exposed to freezing fog conditions for three hours prior to the accident and was accumulating ice. The wheels did not spin up on touchdown, and the spoilers did not automatically deploy. When the first officer (FO) manually deployed the spoilers, maximum auto brake was activated, and the anti-skid protection could not activate because there was no wheel spin-up.

During the landing roll, the target engine pressure ratio (EPR) of 1.3 in reverse thrust was exceeded, which degrades longitudinal control and can cause rudder blanking. The guidance in the Delta manuals did not establish a hard maximum in thrust reverse EPR setting, but target values were listed.

The airport, contrary to the broadcasted Automatic Terminal Information Service (ATIS), did not sand or treat the runways with solid chemicals, except earlier in the morning prior to the airport opening, which was five hours before the accident. When the runway was broomed about 40 minutes prior to the accident, all applied chemicals were brushed off, and no chemicals were reapplied. Additionally, the

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[1] All times published in Coordinated Universal Time (UTC) are converted to EST for consistency with National Transportation Safety Board (NTSB) factual reports (UTC = EST + 5 hours).

runway was never sanded. It also should be noted that the snowfall rate had significantly increased around the time of the accident, and the runway was covered with snow. A preceding aircraft that landed about 20 minutes prior to the accident flight reported poor braking, but no action was taken by the airport.

Throughout the entire morning and through changing conditions, the airport never adjusted the field condition report stating 0.25 inches of snow on all surfaces. Based on the information provided to the flight crew, they expected “good” braking action. Since the accident and based on work done following the Southwest Airlines accident at the Midway Airport in Chicago, Ill., in 2005, a new Advisory Circular (AC 25.32) was issued in December 2015. In this new AC, the conditions provided to the flight crew of 0.25 inches of snow would correlate with “medium” braking action. Medium braking action would have resulted in a landing distance of 7,000 feet, which exceeded the runway length in LGA, and the aircraft would not be allowed to land, in accordance with the Delta Operating Data Manual (ODM).

The airport strictly relied on pilot-reported braking action to determine the condition of the runways. While this is in accordance with regulation and guidance at the time of the accident, it did not provide the flight crew with the best possible assessment of the runway conditions.

In conclusion, ALPA agrees with the NTSB Performance Study conclusion, which states: “The data was incomplete or the effects of these forces on the aircraft were not measured and/or accurately modeled for the exact contribution of each to be determined. What data was available did not make any single event or environmental factor seem likely on its own to be able to impart the yawing moment experienced by the accident aircraft. It is likely that a combination of asymmetric thrust, crosswind, and runway friction caused the aircraft to deviate from the runway heading.” There was no single event that caused this accident, but a series of factors all played a role.

1.0 Factual Information

1.1 History of Flight

The accident crew reported for duty on the day of the accident at 0500 at the Daytona Beach International Airport (DAB) in Florida and flew to ATL, arriving at 0705. The accident flight was scheduled to depart ATL at 0845, but was delayed due to minor maintenance. The flight was scheduled for a flight time of one hour and thirty minutes, and the weather forecast at LGA for the time of arrival was winds 300 degrees at 12 knots, visibility one-half statute miles in snow and mist, with broken clouds at 700 feet above ground level (AGL). While enroute, the flight crew obtained Aircraft Communications Addressing and Reporting System (ACARS) reports of the current LGA ATIS information and field condition reports for LGA. Both the captain and the FO consulted the Delta MD-88 ODM and determined that, based on the current and forecasted conditions, a braking action report[2] of "good" would be needed in order to land safely at LGA. The flight departed from ATL at 0922. Thirty-three minutes later, the crew requested and received a field condition report, which stated braking action advisories[3] were in effect. Runways were reported wet and sanded and deiced with solid chemicals.

At 1018, the crew sent a message to the dispatcher advising that they would need a braking action report of "good"; anything less would make the flight unable to land due to the required landing distance of the aircraft at the expected landing weight. The dispatcher replied that he would pass along a braking action report once he received one. He stated that LGA was landing on Runway 13 at the time.

The captain, who was the pilot flying (PF), briefed that he would fly the Instrument Landing System (ILS) approach to Runway 13 using flaps 40 and maximum auto brakes for landing. Air Traffic Control (ATC) reported that braking action was reported "good" by both an Airbus and a Regional Jet. At 1050, the crew received an ACARS message from the dispatcher also stating that the braking action was "good." With that information, the flight crew decided the runway conditions were suitable for landing.

The captain monitored the wind conditions displayed on his instruments during the approach and noted that they had a 10 to 11 knots crosswind, which changed into a quartering tailwind as they continued. The tower controller reported the winds as 020 degrees at 10 knots just prior to the aircraft landing. The FO, who was the pilot monitoring (PM), called out "approach minimums," and the captain responded that he had the runway in sight. During the interviews, both pilots stated that they saw the runway

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[2] AIM BRAKING ACTION—A report of conditions on the airport movement area providing a pilot with a degree/quality of braking that he/she might expect. Braking action is reported in terms of good, fair, poor, or nil.

[3] AIM: BRAKING ACTION ADVISORIES—When tower controllers have received runway braking action reports that include the terms "fair," "poor," or "nil," or whenever weather conditions are conducive to deteriorating or rapidly changing runway braking conditions, the tower will include on the ATIS broadcast the statement, "Braking action advisories are in effect." During the time braking action advisories are in effect, ATC will issue the latest braking action report for the runway in use to each arriving and departing aircraft. Pilots should be prepared for deteriorating braking conditions and should request current runway condition information if not volunteered by controllers. Pilots should also be prepared to provide a descriptive runway condition report to controllers after landing.

centerline lights and that the runway was white and appeared covered in snow. The flight crew stated they did not expect a snow-covered runway.

After the captain had the runway in sight, he stated that he adjusted his aim point to land the aircraft sooner than briefed, but still in the touchdown zone. The aircraft touched down at 1102, approximately 600 feet from the threshold and on centerline, the captain lowered the nose and deployed the thrust reversers. The captain stated he was looking for a 1.3 EPR setting and, therefore, moved the levers one knob width, which is what the captain had determined typically provided 1.3 EPR. The FO stated that he felt that the speedbrakes did not deploy automatically, so he manually deployed them. The aircraft did not experience the normal deceleration and began sliding to the left. The captain stowed the thrust reversers. The aircraft did not respond to the captain's efforts to steer the nose back to the right and ultimately departed the runway. After sliding further to the left off the runway, the left wing impacted the airport perimeter fence approximately 3,600 feet down the runway.

The FO shut down the engines as he was concerned that the aircraft engine thrust would push the aircraft over the berm and into Flushing Bay. At about 4,500 feet from the threshold, the aircraft severely yawed left, and the nose of the aircraft broke through the fence on the berm. The aircraft came to rest with the cockpit sticking out over the berm. The flight crew stated they could see the drop-off and the water below them. Firefighters approached the FO's partially opened window and advised them to use the right overwing exit. The left overwing exit was not utilized because fuel was spilling out from the left wing. The captain ordered an evacuation through the right overwing exits. The passengers evacuated through the right overwing exit and through the tail cone emergency exit.

2.0 Operations

2.1 Weather

On March 5, 2015, a major winter snowstorm was forecasted by the National Weather Service (NWS). A band of moderate snow was expected over New York, New Jersey, Maryland, and Virginia. The current ATIS the crew received was information Quebec issued at 1551 UTC, which corresponds to 1051. This was 12 minutes prior to the accident. Winds were reported 030 degrees at 11 knots, with a visibility of 0.25 statute miles with moderate snow and freezing fog and a vertical visibility of 900 feet. The temperature was -3 degrees Celsius (26 degrees Fahrenheit), the dew point was -5 degrees Celsius (23 degrees Fahrenheit) ,and the altimeter setting was 30.12 inches of mercury. The ATIS stated that the runways were wet, sanded, and deiced, but had 0.25 inches of snow. All runways and taxiways had three-foot snowbanks on the edges.

> LGA ATIS INFO Q 1551Z. 03011KT 1/4SM SN FZFG VV009 M03/M05 A3012 (THREE ZERO ONE TWO). ILS RY 13 APCH IN USE LND RY 13. DEPART RY 4. B 4 HOLD LINE IN USE.
>
> BRAKING ACTION ADZYS ARE IN EFCT, NO BRKG ACTION ADZY REP AVLB FOR TFC DEPG RY 31. TWY ROMEO RUNUP AREA CLOSE. TWY WISKEY CLOSED. TWY YANKEE YANKEE CLOSED. AIRMET

> SIERRA FOR VISIBILITY. LGA CLASS B SERV AVLB ON FREQ 12. ALL RUNWAYS AND TAXIWAYS HAVE 3 FOOT SNOW BANKS ALONG THEIR EDGES. ALL TAXIWAYS ARE WET AND HAVE BEEN DEICED WITH LIQUID CHEMICAL. ALL RUNWAYS ARE WET AND HAVE BEEN SANDED AND DEICED WITH SOLID CHEMICAL. ALL RWY FIELD CONDITIONS 1/4 INCH WET SN OBSERVED AT 1404 Z. ALL TWY FIELD CONDITIONS 1/2 INCH WET SNOW OBSERVED AT 1404 Z. RY 4/22 HAS, RWY HAS BEEN, SANDED, CHEMICALLY TREATED. RY 13/31 HAS BEEN, SANDED, CHEMICALLY TREATED. BIV OF LGA ARPT. ...ADVS YOU HAVE INFO Q.

Based on the winds reported by Tower just prior to landing at 11:00:32 of 020 degrees at 10 knots, the tailwind component was 4 knots. According to the Delta MD-88/90 Aircraft Operating Manual (AOM), the maximum takeoff and landing tailwind component was 10 knots.

The official NWS Meteorological Aerodrome Report (METAR) for the time of the accident was issued at 1551 UTC (1051) winds 010 degrees at 8 knots, visibility of 0.25 statute miles and vertical visibility of 900 feet, with snow and freezing fog.

There was snow accumulation of 3 inches on the ground from the previous snow event and an additional two inches had accumulated in the hours prior to the accident. Heavy snow was reported after the accident with a snowfall rate of 1 inch per hour. Snow ended at 1815 with a total of 8 inches of new snow fall.

2.2 Regulations for Dispatching an Aircraft

While in this event there were no issues with the dispatch of this aircraft, this accident did identify an issue with dispatching an aircraft to an airport that may have runway contamination which may preclude a landing. When dispatching an aircraft to a runway that is wet or slippery an additional 15% is added to the landing distance, in accordance with 14 CFR 121.195(d). Any snow accumulation or braking conditions are not addressed at this point other than the additional 15 percent.

SAFO 06012, Landing Performance Assessments at Time of Arrival (Turbojets), which was issued in 2006, discusses the obligation of the pilot to perform landing performance assessments based on actual conditions on arrival.

The flight crew was aware of these responsibilities and were actively involved with attempting to get reports and updates for the arrival airport, as well as determine active runway and the landing requirements from the ODM. This is readily apparent from their interviews, as well as the ACARS communications with dispatch.

SAFO 06012 also discusses being able to legally dispatch any aircraft when the aircraft may not be able to land based on a variety of conditions, including runway contamination. It states that:

“Although an airplane can be legally dispatched under these conditions, compliance with these requirements alone does not ensure that the airplane can safely land within the distance available on the runway actually used for landing in the conditions that exist at the time of arrival, particularly if the runway, runway surface condition, meteorological conditions, airplane configuration, airplane weight, or use of airplane ground deceleration devices is different than that used in the preflight calculation."[4]

When an aircraft is dispatched, 14 CFR Part 121 requires operators to use airports that are adequate for the proposed operation. These requirements limit the allowable takeoff weight to that which would allow the airplane to land within a specified percentage of the landing distance available on (1) the most favorable runway at the destination airport under still air conditions and (2) the most suitable runway in the expected wind conditions.

Snow accumulation or braking condition is not addressed. Runway conditions should be considered by the dispatcher prior to dispatch. The flight crew should not be the only line of defense when evaluating runway conditions. If a winter storm with significant snowfall rates is forecast, the airline should be required to consider this information and the impact it will have on braking action prior to dispatch.

2.3 Crew Expectation of Runway Condition

With the information the crew had received from the dispatch release and from the ATIS, current at the time of the approach, the crew was expecting a cleared runway that was chemically treated. At 300 feet, when the aircraft broke out of the clouds, the captain was able to identify the runway and he was able to see the runway centerline lights and the runway edge lights, but the runway did not look like what he was expecting. Based on the information received, he expected to be able to see some part of the runway, but the runway was all white.[5] The FO had a very similar picture in mind, and he was expecting a wet, sanded, and chemically treated runway. He felt that he would have been able to see the runway, its associated markings, and perhaps some slush, but not a layer of snow. When the captain called out that he had the approach lights in sight, the FO looked up and saw the approach lights but not the runway.[6] The captain adjusted his aim point to land within the first 1,000 feet and to stop the aircraft as quickly as possible.[7]

The information the flight crew received led the crew to expect a cleared, mostly bare surface, instead they saw only runway lights with the surface covered in snow. This increased the crew's concern over the quality of the runway conditions. However, the crew had received two good braking action reports from LGA Tower with pilot reports (PIREP) issued by a preceding Airbus and a Regional Jet, and the crew elected to continue the approach and landing.

2.4 Approach

Based on the flight data recorder (FDR), airport surveillance radar (ASR) and surface movement radar (SMR) data,[8] the aircraft flew a stable approach per Delta's operational policies.

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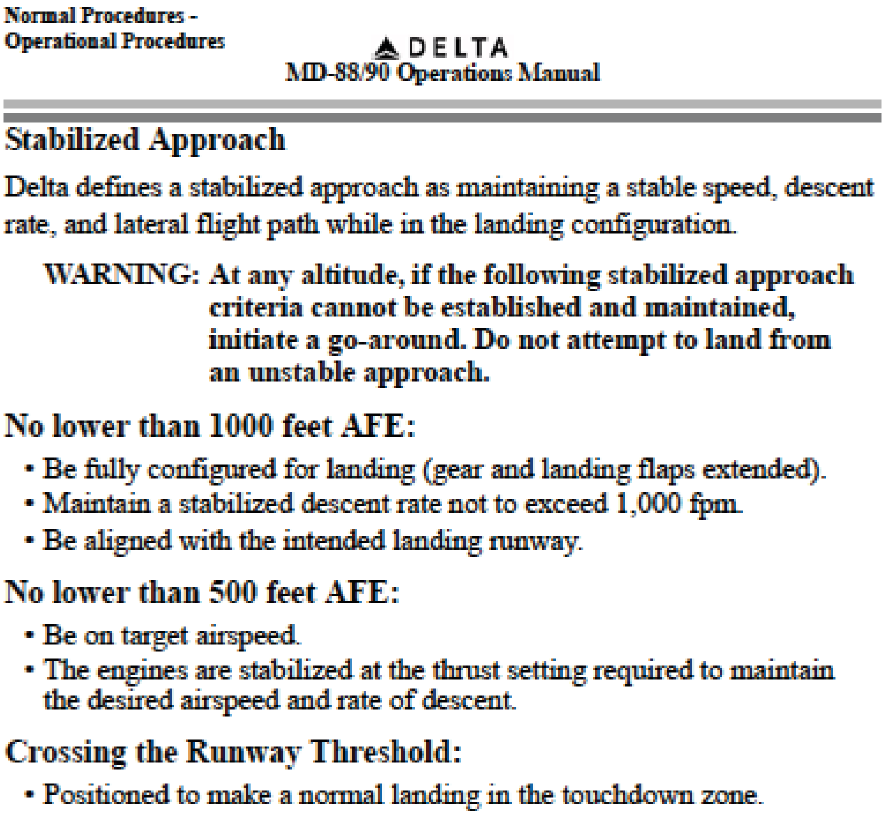
[4] SAFO 06012, issued August 31, 2006

[5] Operations Group Factual Report—Attachment 1—Interview Summaries, page 16

[6] Operations Group Factual Report—Attachment 1—Interview Summaries, page 4

[7] Operations Group Factual Report—Attachment 1—Interview Summaries, page 16

[8] Performance Study, page 8



Normal Procedures -
Operational Procedures

DELTA
MD-88/90 Operations Manual

Stabilized Approach

Delta defines a stabilized approach as maintaining a stable speed, descent rate, and lateral flight path while in the landing configuration.

> **WARNING: At any altitude, if the following stabilized approach criteria cannot be established and maintained, initiate a go-around. Do not attempt to land from an unstable approach.**

No lower than 1000 feet AFE:

- Be fully configured for landing (gear and landing flaps extended).
- Maintain a stabilized descent rate not to exceed 1,000 fpm.
- Be aligned with the intended landing runway.

No lower than 500 feet AFE:

- Be on target airspeed.
- The engines are stabilized at the thrust setting required to maintain the desired airspeed and rate of descent.

Crossing the Runway Threshold:

- Positioned to make a normal landing in the touchdown zone.

Figure 1: Delta MD-88/90 Operations Manual—Normal Procedures, Stabilized Approach

The aircraft touchdown point was calculated as 600 feet from the runway threshold at a speed of 133 knots, which is consistent with the calculated V_{ref} 131 knots +5 knots. The nose wheels touched down approximately 1,200 feet from the threshold.[9] The magnetic heading of the aircraft upon touchdown was approximately 132 degrees with a magnetic runway heading of 134 degrees.

2.5 Landing Distance Assessment

The Delta AOM guidance for landing on contaminated runways included several items applicable to this flight, and the flight crew followed this guidance. The AOM recommended the use of maximum landing flap configuration and the use of maximum auto brake. Furthermore, it stated it is advisable to land as early in the touchdown zone as possible and called for maximum allowable reverse thrust. If side slipping on the runway, reverse is to be selected at idle, and the brakes should be released in order to return to the centerline. The flight crew followed all of this guidance. The aircraft was configured with flaps 40 and maximum auto brake selected. According to the Delta ODM "quick reference chart—operational landing distances" the landing distance for the MD-88 configured with flaps 40 degrees, weighing 127,500 pounds, and using the maximum auto brake selection on a runway with "good"

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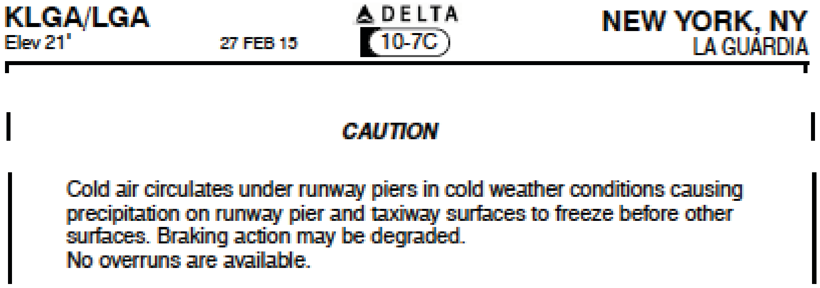
[9] Performance Study, page 48

braking action was 6,050 feet.[10] The landing distance for the same configuration and runway condition but using maximum manual braking was 5,350 ft.

Landing with the same configuration, but with a braking action of less than “good,” the ODM stated a landing distance of 7,700 feet utilizing maximum auto brake setting and 7,150 feet using maximum manual braking for “medium” braking action. Both of these distances would exceed the runway length at LGA of 7,003 feet, and this flight would not have been able to land with any reported braking action of less than “good.”

The aircraft touched down approximately 600 feet from the threshold. Due to the contaminated and short runway, the crew understood the need to maximize the available runway distance for braking.

2.6 Runway Condition on the Pier



KLGA/LGA
Elev 21'
27 FEB 15
DELTA
10-7C
NEW YORK, NY
LA GUARDIA

CAUTION

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 overruns are available.

Figure 2: Delta 10-7 Page, Caution for Landings on LGA Pier

Runway 13 at LGA is 7,003 feet long. The first 1,000 feet is constructed of a concrete pier. Cold air circulates under the pier causing the surfaces on the pier to freeze before the surfaces of the rest of the airport in cold weather conditions.

The LGA Runway 13 surface temperature measured at a sensor mounted in the runway on the pier was 32.2 degrees Fahrenheit. This temperature was constant from 0751 to 1651, while the air temperature during the same period of time dropped from 31.6 degrees to 24.5 degrees. During the period from 0851 to after the accident occurred, freezing fog was reported in the LGA ATIS. These fog droplets freeze upon contact with exposed objects and form a coating of rime and/or glaze.[11] With air temperature below freezing, water droplets in fog can become super cooled. In this form, super cooled liquid droplets freeze when in contact with an object.

The constant runway surface temperature is consistent with super cool liquid droplets releasing latent heat during the process of freezing to the pier. This keeps the pier at a constant surface temperature measured at 32.2 degrees Fahrenheit[12] while accumulating ice.

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[10] Landing distance is based on the landing weight found in the speed card in the cockpit. Operations Group Factual Report—Attachment 4

[11] National Weather Service Glossary

[12] Airports Group Factual Report—Attachment 1—Snow Log Pages 3–5

2.7 MD-88 Spoiler System

The MD-88 has spoiler panels on each wing that are used to reduce lift and induce drag. The two outboard panels on each wing function as flight spoilers. They extend for roll augmentation in flight. They assist the ailerons in providing a roll moment when the control wheel is rotated past a certain position. They also provide a speedbrake function by creating drag when deployed by the speedbrake handle. When used together, these two control inputs are resolved through the spoiler mixer control, which varies the extension of spoilers on the wings based on inputs from these control inputs.

These panels also induce additional drag and spoil lift when extended to the ground extension position. This is controlled by the speedbrake handle and protected from deployment in flight by guards in the speedbrake handle track, as well as devices in the speedbrake handle control system. To augment this function during landing rollout, two additional spoiler panels at the inboard section of the wing are dedicated to ground spoiler deployment. These two inboard ground spoilers require speedbrake handle movement to the ground extension position and wheel spin-up detection through the wheel speed transducers to deploy. In absence of wheel spin-up, nose gear WOW completes the circuit to extend the ground spoiler panels.

When armed, the MD-88 auto spoiler system provides timely activation of spoilers at touchdown without pilot action. Auto spoiler arming is preselected during the approach by moving the speedbrake handle to the armed position. On touchdown, the speedbrake handle is moved to the ground extension position by an actuator. In order to auto-deploy the spoilers, the system needs input from either main wheel spin-up or nose wheel WOW. If these input parameters are not provided to the system, the actuator will not deploy, and the speedbrake handle will not automatically move to the extend position. If automatic deployment does not occur, the pilots must manually deploy the spoilers by moving the speedbrake handle to the ground extension position.

During the flare, the indicated airspeed began to reduce, and about two seconds later at 11:02:16 a vertical spike or increase in vertical acceleration occurs. This spike is consistent with the aircraft touching down on the runway. The acceleration decreases to less than 1.0 G and a second vertical spike of about 1.3 Gs, slightly firmer than the first.[13] This trough between spikes indicates a rebound from strut compression. The acceleration was less than 1.0 G for about 1.4 seconds. This is not sufficient for the aircraft to become airborne. The pilots reported a normal and firm touchdown. The vertical acceleration recorded is consistent with other landings of MD-88s, including the preceding Delta flight landing at LGA.[14]

Ground spoilers consist of three spoiler panels on each wing. Two outboard panels also function as flight spoilers. They are used for roll augmentation in flight. They assist the ailerons in providing a roll moment when the control wheel is rotated past a certain position. They also provide a speedbrake function by creating drag when deployed by the speedbrake handle. When used together, these controls are

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[13] FDR Group Factual Report, page 5

[14] FDR Group Factual Report—Attachment 1, page 5

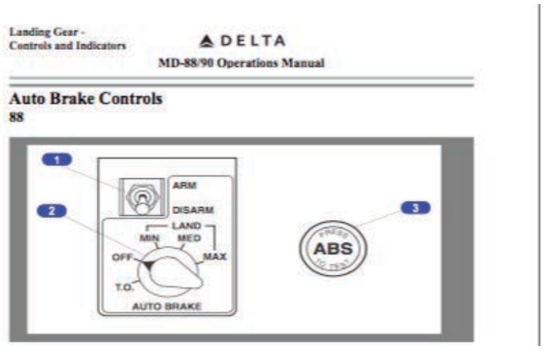
resolved through the spoiler mixer control, which varies the extension of spoilers on the wings based on inputs from these controls.

These panels also induce drag and spoil lift when extended past normal roll extension to ground extension position. This is controlled by the speedbrake handle and protected from deployment in flight by guards in the speedbrake handle track, as well as devices in the speedbrake handle control system. To augment lift dissipation during landing rollout, two spoiler panels at the inboard section of the wing are dedicated to ground spoiler deployment. These spoilers require speedbrake handle movement to the ground extension position and wheel spin-up detection through the wheel speed transducers to deploy. In case of loss of wheel spin-up, nose gear shift detection completes the circuit to extend the ground spoiler panels.

Spoiler extension is recorded at 1 hertz (Hz) (once per second) while vertical acceleration is measured at 8 Hz. The left outboard and right inboard spoiler position increases from 0 to 60 degrees, which is full ground extension between 11:02:17 and 11:02:19, and the vertical acceleration peaks at 11:02:18, consistent with movement of the speedbrake handle to the full aft, ground spoiler command position. The FDR data is consistent with the FO's account that he did not believe that the spoilers auto-deployed and moved the speedbrake handle to manually deploy them. Vertical acceleration again shows a small dip and smaller peak at 11:02:20 EST.

2.8 MD-88 Auto Brake System

The auto brake system (ABS) provides reliable automatic symmetric braking to ensure consistent deceleration on landing roll. The auto brake system is preselected to provide appropriate braking schedules. The ABS modulates brake pressure to control brake application.

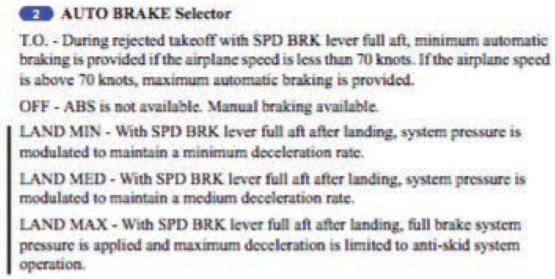


Landing Gear -
Controls and Indicators

DELTA
MD-88/90 Operations Manual

Auto Brake Controls
88

Figure 3: Delta MD-88/90 Operations Manual, Auto Brake Control Panel



2 **AUTO BRAKE Selector**

T.O. - During rejected takeoff with SPD BRK lever full aft, minimum automatic braking is provided if the airplane speed is less than 70 knots. If the airplane speed is above 70 knots, maximum automatic braking is provided.

OFF - ABS is not available. Manual braking available.

LAND MIN - With SPD BRK lever full aft after landing, system pressure is modulated to maintain a minimum deceleration rate.

LAND MED - With SPD BRK lever full aft after landing, system pressure is modulated to maintain a medium deceleration rate.

LAND MAX - With SPD BRK lever full aft after landing, full brake system pressure is applied and maximum deceleration is limited to anti-skid system operation.

Figure 4: Delta MD-88/90 Operations Manual, Auto Brake Selector and Deceleration Rates

ABS schedule is selected on the ABS panel by rotating the auto brake selector. It is then armed for operation by placing the ABS switch in the ARMED position. The auto brake system activates when the speedbrake handle is moved to the full aft position during touchdown.

The crew of this flight selected LAND MAX. Delta MD-88/90 Operations Manual, Contaminated Runway, Landing, SP 16.14 contains the following guidance:

“Consider using MAX auto brakes for maximum stopping effectiveness.”

Selecting “LAND MAX” would provide full brake system pressure to the right brake pressure manifold. In most landing situations, braking rate would be the maximum available and limited only by modulation of the antiskid system.

The auto brakes in the MAX position has a 1 second delay to activation.[15]

2.9 Antiskid

The MD-88 has antiskid protection for main wheel braking. The antiskid system compares rotation speed between wheels during braking in ground operations. It then makes a determination if a tire is approaching a skid and modulates brake pressure to that wheel. The antiskid system requires wheel rotation above a certain speed to operate.[16]

2.10 Aircraft Performance After Touchdown

The aircraft touched down about 600 feet from the beginning of the touchdown zone. This would place it in about the center of the runway pier section, which extends over Flushing Bay. Because of ice accumulation due to freezing fog and snow, the surface of the pier would be icy. On touchdown, the FO noticed that the auto spoilers did not activate.

The FO stated that it felt to him the spoilers took too long to deploy. He waited a second longer than normal and then manually deployed the spoilers.[17] This is in accordance with the DAL FCTM, which

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[15] Delta Operations Manual, Vol 2, page 14.20.7

[16] Delta FCTM, page 6.19: “When brakes are applied on a slippery runway, several skid cycles occur before the antiskid system establishes the right amount of brake pressure for the most effective braking.”

[17] Operations Group Factual Report—Attachment 1—Interview summaries, page 4

states that the aircraft should be flown firmly onto the runway at the aiming point. Avoid holding the aircraft off the ground. Be prepared to manually deploy spoilers, if automatic deployment does not occur, as wheel spin-up may be delayed.[18]

At this point, three aural indications of a caution from the CAWS are recorded on the CVR including "spoilers." The CAWS spoilers caution is annunciated when flaps are in the landing position, the speedbrake handle is not in the retracted position, and the aircraft is in flight. The FDR records movement of the left outboard and right inboard flight spoiler panels. The left outboard spoiler first recorded motion at 11:02:17.5 (1.5 seconds after main gear touchdown), and both spoilers showed full deployment soon after. The two inboard ground spoiler panels require input from the proximity switch electronics unit (PSEU) to extend. The PSEU uses wheel spin-up or nose strut compression inputs to determine ground status. Therefore, the ground spoiler panels would have deployed at nose wheel touchdown, recorded at 1102:19. The CAWS "spoilers" caution ceases at this point, as well.

Braking action is a function of downforce on the braking wheels (main) and the surface friction. The failure of the spoilers to auto deploy was most likely the failure of the main wheels to get sufficient traction on the icy surface of the pier section. The subsequent delay in spoiler activation and the further delay in ground spoiler movement would have caused a period after touchdown of reduced downforce. During this time, speedbrake handle movement to the deployed position by the FO would have caused maximum auto brake activation after a 1 second delay. If wheels were subject to brake pressure before adequate rotation speed, they would lock quickly. Locked wheels would not provide useful braking or cornering force. The wheels would stay locked unless rotation and antiskid were regained. In the case of all four wheels being locked, this would require a complete release of the brakes and then reapplication. During testimony for the American Airlines (AA) Flight 1420 accident public hearing, a NASA engineer stated that abnormal antiskid operation would be expected with low to no wheel spin-up accelerations on a low to no traction runway surface and delayed spoiler deployment.

The FO stated that he did not feel any action from the auto brakes and that he could feel the spoilers and the thrust reverse take effect, but not the wheel brakes.[19] All three flight attendants stated that the aircraft did not decelerated as expected.[20] The statements indicate that they did not feel the sudden braking onset usually associated with landings.

As the aircraft continued down the runway, the elevators' nose-down deflection increased. This would have further reduced downforce on the main gear and shifted weight to the nose gear. Added weight to the nose gear would have also increased its cornering force. The aircraft began to rotate with the nose moving left and the tail moving right. The main gear remained near the runway center. The aircraft did not resist this force in any discernable way, indicating little or no cornering force.

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[18] Delta FCTM—Section 6.15—Landing on wet or slippery runways

[19] Operations Group Factual Report—Attachment 1—Interview summaries, page 4

[20] Survival Factors—Attachment 4—Interview summaries

Figure 5: Passenger Photograph out of the left side window at the 500 foot runway marker. Note retracted spoiler panels.

2.11 Thrust Reversers

The thrust reversers redirect the thrust in approximately a 45-degree angle above and below the engine from the direction of forward thrust. This provides additional stopping capabilities in addition to the wheel braking, enabling shorter landing rollout distances.

The Boeing Flight Operations issued a bulletin dated November 5, 2002, to all operators of MD-80 series aircraft in response to an NTSB recommendation concerning use of reverse thrust under wet or slippery runway conditions. This bulletin cautions that 1.3 engine pressure ratio (EPR) should be used as the maximum reverse thrust power under wet or slippery runway conditions. Similar guidance was included in the All Operator Letter (AOL) from February 15, 1996, that states that reverse EPR of above 1.3 EPR can result in rudder blanking reducing the directional control.

Boeing provided this information to operators (airlines) as operational guidance. The operators then modified their manuals and procedures as necessary. Delta FCTM 6.22 included this note:

“Note: (88) Normal dry runway reverse thrust minimum is 1.3 EPR, target 1.6 EPR.”

DAL MD-88/90 Operations Manual SP.16.10 included this statement:

"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."

Delta's manuals did address the loss of rudder and subsequent loss of directional control due to EPR greater than 1.3 in the caution statement above. This statement begins the section titled "Landing on Wet or Slippery Runways" However, this statement is not directly specific guidance for slippery or wet runway operation. Further this warning was made ambiguous with the additional statement that up to maximum reverse thrust may be used, as necessary, as long as the aircraft is aligned with the runway. This same section of the FCTM discusses reverse EPR application:

On wet, contaminated, or slippery runways, immediately after nose 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.

Although 1.3 EPR is again mentioned here, it is not defined as either target or limit. Nor is there any additional reference to relate to control difficulties.

As Delta flight 1086 exceeded the 1.6 EPR target, the aircraft began to yaw left. Within 1.5 seconds of the left yaw moment, the thrust was reduced from the maximum and the reversers were fully stowed within 4 seconds. At this time the aircraft was approximately 5 feet to the left of the runway centerline.

The maximum EPR setting on the accident flight during the use of reverse thrust was 2.09 on the left engine and 1.9 on the right engine. Higher than Boeing-recommended reverse thrust EPR settings are not uncommon for Delta aircraft data examined in this accident. The NTSB examined quick access recorder (QAR) data from 59 previous landings of this aircraft. On half of these landings, an EPR setting above 1.6 for more than 4 seconds was recorded. This included 6 other landings on contaminated runways. The preceding Delta Airlines MD-88 aircraft landing at LGA recorded EPR values reaching 1.8 on the left engine and 1.5 on the right engine. This aircraft reported no landing difficulties. MD-80 Series aircraft data from other airlines was not examined during this accident.

2.12 Manual Braking

As the thrust reversers were stowed at 11:02:24.5, the brake pressure in the left system was recorded at 3000 PSI. Shortly thereafter, the pressure in the left system dropped, and an increase in the right brake system was recorded. This is consistent with the application of manual brakes. The captain applied right differential brake pressure which would correspond to action to correct the left yaw that the aircraft was experiencing at that time. Application of manual braking by depressing brake pedals will disarm the auto brake system.

2.13 Use of Rudder

Right rudder input was first recorded at 11:02:20.5 and increased over the next 4 seconds to a value of about 12 degrees. During this time the thrust reverse EPR setting was in excess of 1.6, and the rudder has lost most of its effectiveness. The rudder deflection reverted back to almost zero within the next second, and at around the same time the thrust reversers were stowed. Another second later, right rudder deflection was approaching the maximum recorded value of 21 degrees. The rudder had regained effectiveness at this time as the thrust reversers had been stowed. The maximum deflection of 21 degrees was reached at 11:02:26, two seconds after the thrust reversers had been stowed. At this point, the heading did not increase anymore.

2.14 Control-Column Position vs. Elevator Position

The elevators are powered aerodynamically by movement of a control tab on the trailing edge of each elevator. This control tab is moved by cables attached to the control column. As the control column is moved forward to aft, the control tab moves from up to down. This creates an aerodynamic force that drives the elevator from down to up. The actual elevator position is the result of all aerodynamic forces on the elevator and may vary from specific control-column position in different aircraft configurations and flight conditions.

The FDR recorded the elevators at a flight position around 2 degrees nose down (-2) moving to a position around -15 degrees after touchdown. At the same time, the control column moved from around 10 degrees nose up to around 5 degrees or less nose down. The maximum parameter for elevator travel is 15 degrees (displayed as minus) trailing edge down, and for control column is 10 degrees (displayed as minus) forward.

This placed the elevators at or near the maximum full-down position for most of the ground roll from ground shift (WOW) leading through loss of heading control. The elevators reached 15 degrees nose down one second before the heading began to move left and varied between 15 and 12 degrees.

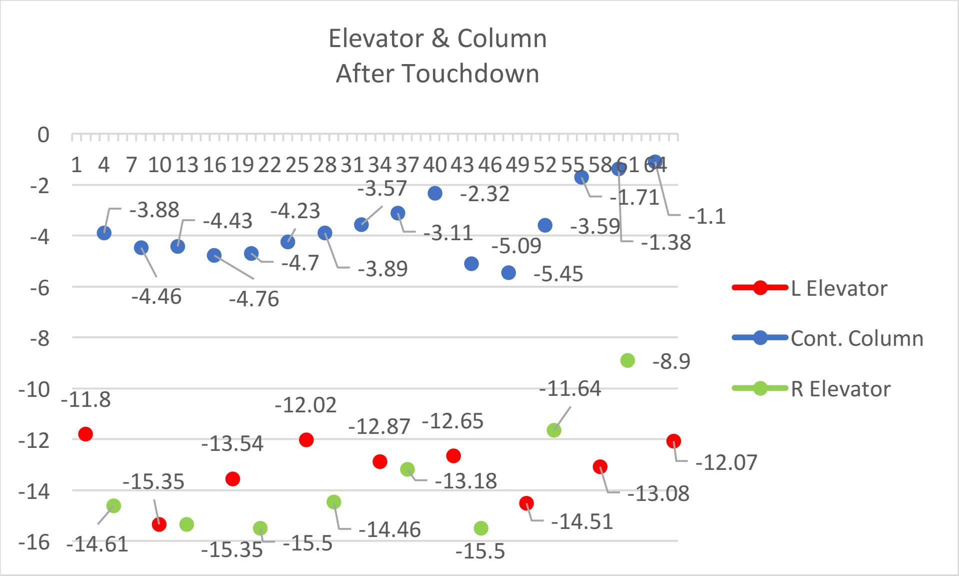


Figure 6: Elevator and Control-Column Position After Nose-Gear Touchdown

The elevators do respond and follow direction of control-column movement during this period. But their movement appears out of proportion to displacement of control-column movement toward nose down. For example, the control column remained within 1 degree of 4 degrees of nose-down column position, about half of its forward travel, for most of the first 10 seconds. However, the elevators remained between 11 and 15 degrees; two thirds to full travel. The left elevator showed greater travel than the right. The left reverse EPR was also higher than the right during this period. The effect seems somewhat diminished when reversers stowed.

Comparing the FDR data from the previous MD-88, the elevator displacement was more in proportion to control-column position during the same period after touchdown. However, the left EPR reached 1.7 during initial application of reverse. The left elevator exceeded 10 degrees and reached 12 degrees nose down with control wheel not exceeding 5 degrees. During this same period, the right EPR remained closer to 1.3 and peaks at 1.5.

This suggests an increase in elevator sensitivity toward trailing-edge down during reverse thrust, most noticeable above about 1.5 EPR, in these two flights.

2.15 Lifting Forces on the Rear Section

The elevator trailing edge in a down position causes a nose-down attitude by creating lift on the tail. On the ground, this will lift the rear section of the aircraft and, therefore, decrease the downward force on the main landing gear. Any loss in downforce reduces the ability of the tires to produce braking and cornering forces. This has a negative impact on the already decreased braking action on the contaminated runway. The Delta FCTM states to “avoid excessive forward control-column pressure in order to maintain maximum braking effectiveness and to reduce possibility of nose wheel spray."[21] Pilots holding control column just forward of the center position would not expect to be causing excessive elevator movement.

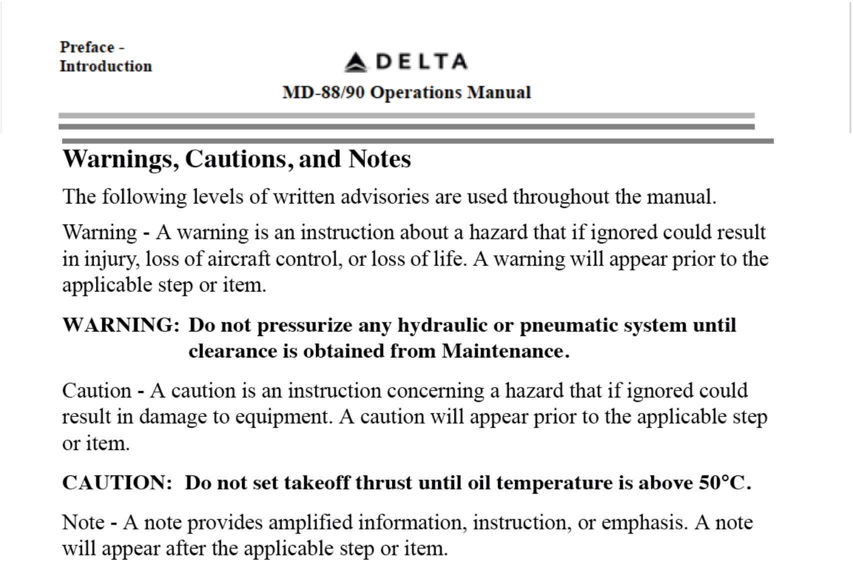
Additionally, the thrust reversers exhaust gas is deflected at a 45 degree angle from the direction of thrust above and below the engine.[22] This efflux pattern will have a very similar impact as the elevator training edge in a down position and causes an upward force on the rear section of the aircraft and reducing the downforce on the main landing gear.

The flight crew followed guidance from the FCTM on braking, pitch, and use of reverse thrust.

2.16 Discrepancies in Manuals and Guidance

2.16.1 Use of Caution and Warning

The AOM referenced caution and Warning statements to emphasize potential hazardous conditions. Several statements labeled as "caution" better describe instructions that meet the definition as warnings in accordance with the Delta Operations Manual Vol 1–P1.2.4. This could affect the pilot's interpretation of the threat noted in these statements.



Preface - Introduction

DELTA

MD-88/90 Operations Manual

Warnings, Cautions, and Notes

The following levels of written advisories are used throughout the manual.

Warning **-** A warning is an instruction about a hazard that if ignored could result in injury, loss of aircraft control, or loss of life. A warning will appear prior to the applicable step or item.

WARNING: Do not pressurize any hydraulic or pneumatic system until clearance is obtained from Maintenance.

Caution **-** A caution is an instruction concerning a hazard that if ignored could result in damage to equipment. A caution will appear prior to the applicable step or item.

CAUTION: Do not set takeoff thrust until oil temperature is above 50°C.

Note **-** A note provides amplified information, instruction, or emphasis. A note will appear after the applicable step or item.

Figure 7: MD-88/90 Operations Manual Vol 1—Page P1.2.4, definitions

In the following example, the "CAUTION"" should be a "WARNING" because the potential loss of control can lead to injury or loss of life based on the information from Figure 7 above.

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[21] FCTM Section 6.16—Landing on slippery runway

[22] Airworthiness Group Factual Report—Addendum 1, page 3

"CAUTION: Reverse thrust above 1.3 EPR may blank the rudder and degrade directional control effectiveness . . ."[23]

"CAUTION" and "WARNING" statements throughout the manual and should be validated.

2.16.2 EPR Limitation

Boeing guidance of 1.3 EPR maximum for the use of reverse thrust is described as a "limit."[24] Guidance in the Delta manuals was different, as stated in the FCTM, which states the following: "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."[25] A newsletter from April 2014 included reference to EPR target values: "**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."[26]

Delta manuals called out targets for EPR settings as opposed to limits called for by Boeing. Delta guidance also allowed for the use of EPR setting in excess of 1.3, up to the maximum, on contaminated runways as long at directional control is maintained.

2.16.3 Thrust Reverse Deployment and Engine Acceleration

Practical experience shows that due to variation in thrust reverser rigging, engine configurations, bleed air configurations, and engine idle, large variations in EPR settings and engine acceleration during application of reverse thrust may occur. This variation occurs across the fleet and even between engines mounted on the same aircraft.[27] This results in a split between left and right engine thrust, which induces a yaw moment and complicates establishing a specific target EPR. Reverse thrust is most effective at high airspeed; therefore, establishing appropriate reverse thrust quickly after touchdown results in the most efficient deceleration.

The FCTM emphasized early establishment of reverse thrust.

"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."[28]

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[23] Delta MD-88/90 Flight Crew Training Manual—Landing 6.15
[24] Operations Group Factual Report—Attachment 19—Boeing All Operator Letter AOL-9-058
[25] Delta MD-88/90 Flight Crew Training Manual—Landing 6.15
[26] Operations Group Factual Report, page 28
[27] Performance Study, page 42
[28] Delta FCTM, page 6.15-17

"The importance of establishing the desired reverse thrust level as soon as possible after touchdown cannot be overemphasized. This minimizes brake temperatures and tire and brake wear, and reduces stopping distance on very slippery runways."[29]

"Note: 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."[30]

"**Note:** Spoilers fully deployed, in conjunction with maximum reverse thrust and maximum manual antiskid braking provides the minimum stopping distance."[31]

However, the importance of carefully establishing accurate and symmetrical reverse thrust is reflected in fleet publications:

Boeing states the following:

"Apply reverse thrust to idle reverse thrust detent. After reverse thrust is verified, gradually increase reverse thrust as required to no more than 1.3 EPR."[32]

Delta FCTM states: "After reverse thrust symmetry is verified, gradually increase thrust as required."[33]

"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 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"[34]

Guidance in the Delta manuals at the time of the accident recommended to establish reverse thrust as soon as possible, as reverse thrust is most effective in high airspeed. The FCTM and Boeing guidance both included guidance that suggests that symmetrical reverse thrust should be verified and then gradually increased. This is contradicting guidance, as it is impossible to establish desired reverse thrust as soon as possible and at the same time verify symmetry and gradually increase reverse thrust.

2.16.4 Control-Column Usage

Guidance provided by both Delta manuals and Boeing discussed the need of forward control-column pressure in order to aid directional control. Increased forward pressure increases weight on the nose wheel and provides improved nose-wheel steering. In the same guidance, however, Boeing stated that the use of too much forward pressure as this may unload the main gear and cause reduced braking action. Reduced braking action will delay auto-spoiler deployment.

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[29] Delta FCTM, page 6.18
[30] Delta FCTM, page 6.14
[31] Delta FCTM, page 6.14
[32] Operations Group Factual Report—Attachment 19—Boeing All Operator Letter AOL-9-058
[33] Delta FCTM, page 6.16
[34] Operations Group Factual Report, page 28

Delta FCTM stated: “On touchdown, take positive action to lower the nose wheel to the runway and maintain moderate forward pressure on control column to assist in directional control. Avoid excessive forward control-column pressure in order to retain maximum braking effectiveness and to reduce possibility of nose wheel spray. Hydroplaning may cause delayed Auto Spoiler deployment.”[35]

FCTM: “Slight forward pressure on the control column may be needed to achieve touchdown at the desired point and to lower the nose wheels to the runway. After lowering the nose wheels to the runway, hold light forward control-column pressure and expeditiously accomplish the landing roll procedure. Full reverse thrust is needed for a longer period of time.”[36]

FTCM: “On touchdown, take positive action to lower the nose wheel to the runway and maintain moderate forward pressure on control column to assist in directional control.”[37]

Boeing All Operator Letter stated: “When operating on wet or slippery runways, apply sufficient down elevator after nose gear contact to increase weight on the nose wheel for improved steering effectiveness, but not an excessive amount which will unload the main gear and reduce braking efficiency”[38]

These statements illustrate the challenges presented to the pilots between insufficient nose-wheel steering and loss of brake effectiveness and cornering force of the main gear. Although the importance of correct control-column position is emphasized, no objective guidance to achieve this is provided.

2.16.5 Directional Control Loss on Slippery Runways

Delta Air Lines manuals offered guidance for landing on slippery runways for flight crews to consider. This included guidance about the touchdown zone and the use of the thrust reverser and directional control.

The Boeing AOL gave guidance for regaining directional control if lost on a slippery runway during use of reverse thrust. Delta manuals also recognized this threat and gave guidance. However, in both cases the guidance varied as published and may cause unresolved conflicts for pilots trying to respond to a skid.

Boeing AOL 9-058, 1996: “If difficulty in maintaining directional control is experienced during reverse thrust operation, reduce thrust as required and select forward idle if necessary to maintain or regain control. Do not attempt to maintain directional control by using asymmetric reverse thrust.”

Boeing FOB 80-02-03 “reiterates information currently incorporated in the Boeing MD-80 Flight Crew Operating Manual.” The guidance for regaining directional control is virtually unchanged. However, the bulletin includes the statement that crews identify reverse-thrust EPR targets during approach briefings. It also advises: “After thrust-reverser deployment on rollout, the Pilot-Not-Flying (PNF) duties should

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[35] Delta FCTM, page 6.16
[36] Delta FCTM, page 8.18
[37] Delta FCTM, page 6.16
[38] Operations Group Factual Report—Attachment 19—Boeing All Operator Letter AOL-9-058

include monitoring reverse-thrust deployment and advising the Pilot-Flying (PF) of excessive EPR settings should they occur."

Delta FCTM had a section labeled "Landing on Wet or Slippery Runways," which stated the following regarding skid:

"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."

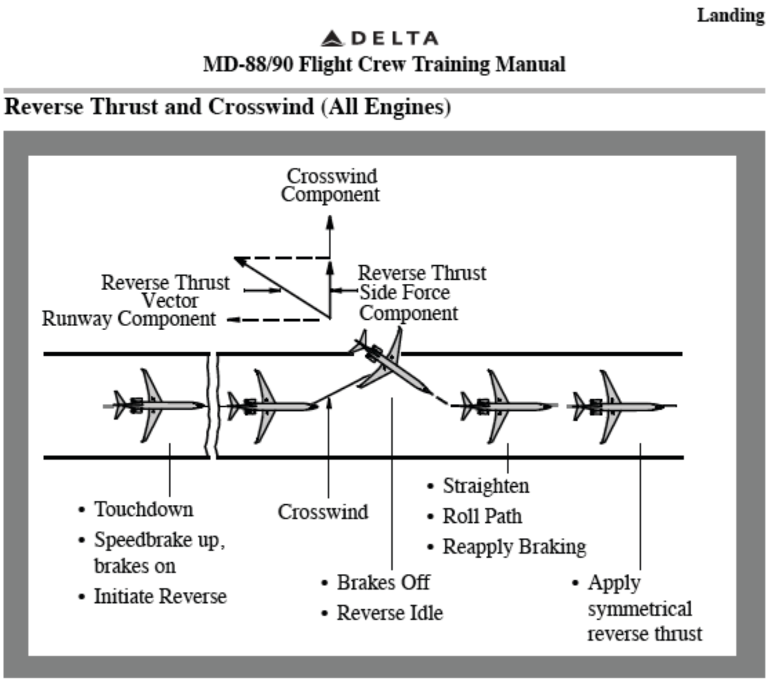
This section incorporated Boeing guidance on directional control. It also commanded the release of brake pressure, which aids in restoring cornering force to the main wheels. The goal of these actions is to realign the airplane with the runway track as soon as possible so that braking forces can be restored. Returning to centerline is therefore discouraged.

The AOM, VOL 1, SP.16 "Guidelines for Contaminated Runways" has bullet points for "landing." Two of these bullets address directional control:

- 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.

The first point commands the use of reverse idle and does not mention forward idle. It also states to release brakes. These actions are to "return to the centerline." Returning to centerline is in conflict with the guidance in the FCTM which states that "correct[ing] to runway centerline may delay deceleration efforts and aggravate skid conditions."

During the accident landing, the aircraft remained near the center of the runway as the heading began to drift left. As the airplane turned, the cockpit approached the left side of the runway. This would be perceived by the pilots as the aircraft drifting toward the upwind side of the runway. This perception would be confusing to the pilots, as guidance in the second bullet, as well as the figure from the FCTM below, would indicate the airplane would drift downwind during reversing on slippery runways.



Landing

DELTA

MD-88/90 Flight Crew Training Manual

Reverse Thrust and Crosswind (All Engines)

Figure 8: Delta FCTM guidance reverse thrust operations in crosswind conditions

The FCTM in a section labeled "Reverse Thrust" states: "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." Although this addressed engine limits and reverse-thrust abnormalities, it did not specify a callout of excessive EPR settings as addressed in the Boeing FOB.

2.16.6 Training

In the recurrent training cycle from July 2012 to March 2013, Special Purpose Operational Training (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 pilots' training records indicated that they received this training module.

Here, the EPR guidance included specific mention of thrust above 1.3 having potential to blank rudder and degrade directional control. However, there was no mention of 1.3 as a specific EPR limit.

Once again, loss of directional control is addressed. Here, the recovery guidance significantly differed from the guidance in the FCTM: "Reduce reverse thrust to idle reverse" is trained. No mention of the option of forward idle was made. "[H]old forward stick [control column]" is not mentioned in any other recovery guidance to this point. The amount of forward column is not discussed in guidance, nor is any warning offered on its effect on braking. This could easily be interpreted that up to full-forward control column would be appropriate.

The training guidance stated the objective "to regain centerline track." This is again in conflict with guidance in the FCTM, which emphasizes restoring aircraft direction and that "correct[ing] to runway centerline may delay deceleration efforts and aggravate skid conditions."

The net effect of this conflict in guidance and training for loss of directional control was that effective pilot action in such an event would be very likely unpredictable or, worse, could aggravate the condition through improper action or the inability to react at all.

The guidance below describes that it is advisable to consider delaying the use of the thrust reversers. This will cause a tradeoff between the shortest achievable stopping distance and ensuring directional control is maintained.

"Land as early in the touchdown zone as possible."[39]

"If directional control is compromised, reduce reverse thrust to idle reverse and hold forward stick pressure to regain centerline track."[40]

"On wet, contaminated, or slippery runways, immediately after nose-gear touchdown, maximize antiskid 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."[41]

"**Note:** Consider delaying thrust reverser deployment until nose wheel touchdown, so that directional control is not affected by asymmetric deployment."[42]

"**Reverse Thrust and Crosswind (All Engines):** This figure[43] shows a directional control problem during a landing rollout on a slippery runway with a crosswind. 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."[44]

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[39] Delta Operations Manual Vol 1, SP 16.14
[40] Delta Training Module CG 603
[41] Delta FCTM, page 6.16
[42] Delta FCTM, page 6.12
[43] See Figure 8
[44] Delta FCTM, page 6.25

2.17 Special Winter Operations Airport (SWOA)

Delta designates SWOA airports due to several factors including climate, snowfall, or elevation. Additionally, the runway length, as well as airport infrastructure and the use of airport runway friction measuring equipment is taken into account. At the time of the accident LGA was not designated a SWOA airport. Since the accident, Delta has included LGA on the list of SWOA airports. With the guidance in the SOWA evaluation in the Delta Airway Manual (AM), the crew would have not been allowed to land with the latest reported winds of 020 degrees at 10kts. The tailwind component in these wind conditions was 4 knots. The SWOA pilot/dispatcher guide stated that if the tailwind component is 4 knots or more, takeoffs and landings are prohibited.[45] Therefore, if LGA had been designated as an SWOA airport by Delta at the time of the accident, the flight crew would have not been able to land at LGA based on the tailwind component.

3.0 Airport

3.1 Airport Information

LGA was certified by the Federal Aviation Administration (FAA) as a 14 CFR Part 139 airport with index D aircraft rescue and firefighting (ARFF). The airport's elevation is 20.6 feet, and the airport has two runways: 13/31, which was 7,003 feet long, and 04/22, which was 7,001 feet long. Both runways were grooved.

3.2 LGA Snow Removal Plan

LGA had an approved snow removal plan in accordance with 14 CFR Part 139.313. LGA was regularly closed between 0000 and 0600 each day; during this overnight shift, the runways and taxiways were treated with solid chemicals and sanded in preparation for the forecasted snowfall. LGA issued a Notice to Airmen (NOTAM) at 0745 stating that the runway had been sanded and chemically treated. By 0851 a total of 1.8 inches of snow had fallen, and two NOTAMs were issued at 0902 and 0903 indicating 0.25 inches of wet snow on the runways. These were the last NOTAMs issued prior to the accident, which occurred at 1102. The flight crew requested a field report at 0955, which again stated that the runways were chemically treated. At 1018, the flight crew was told by the dispatcher that Runway 13 was closed as the airport was sweeping the runway. The blue team[46] began clearing the runway at 1006 and completed the clearing at 1035, which was 29 minutes prior to the accident. At this time ATIS "Papa" was current.

ATIS information Papa (special) was issued at 1024 and reported a temperature of -3 degrees Celsius with snow and freezing fog and 0.25 mile visibility. Winds were 040 at 7 knots. It stated that "all runways are wet and have been sanded and deiced with solid chemical." It also stated that "all runway field

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[45] Delta Airway Manual, page WX.2.29

[46] LGA had several color coded teams clearing different areas of the airport. The Blue team was assigned to clear Runway 13/31.

conditions ¼ inch wet snow observed at 1404Z" and that braking action advisories were in effect. Runway 31 was not treated with chemicals during the last clearing operation per the statement of the LGA snow coordinator.[47] This information is in contradiction with ATIS "Papa" and the following ATIS "Quebec." During the clearing operation, the solid chemicals were cleared off the runway and not reapplied.[48]

ATIS information "Quebec" was issued at 1051 and current at the time of the accident. It reported a temperature of -3 degrees Celsius with snow and freezing fog and 0.25 mile visibility. Winds were 030 at 11 knots. It stated that "all runways are wet and have been sanded and deiced with solid chemical" and that braking action advisories were in effect. It also stated that "all runway field conditions ¼ inch wet snow observed at 1404Z."

Both ATIS "Papa" and "Quebec" stated that the runway was sanded and chemically treated. However, neither had been done recently. The runway snow was only broomed. The last time the runway was actually chemically treated was in the morning before 0450 when the airport was closed. The snow coordinator stated that it was not standard procedure to apply chemicals and/or sand during the last runway clearing prior to arrivals. He added that if they had chemical deicing material in the plow and the braking action reports were fair or poor, they would have begun treating the runway. While it is within regulations to issue NOTAMs valid for longer periods of times, during periods of rapidly changing weather, NOTAMs including runway conditions should be updated frequently as the conditions are constantly changing. A NOTAM should not have information about chemically treated runways if the information is not accurate, meaning such a NOTAM should not be valid after activities that would have removed the chemicals from the runway surface. The airport authority did not adjust the field condition report.

LGA does not close runways for snow removal or treatment, but works on "hot runways"[49] meaning they wait for gaps in arrivals and departures in order to minimize impact on flight operations.

Prior to the landing of the accident aircraft at 1102, a United Airlines (UAL) A319 landed at around 1043 local time and reported braking as ". . . medium at touchdown and getting worse than that here on rollout . . . We are going to call it poor down here where we are coming off at Mike." After a discussion with the ground controller on whether fair or medium is the correct terminology of reporting braking action, UAL 462 replied that according to the Aeronautical Information Manual (AIM) the correct terminology is medium. The ground controller disagreed and insisted that the new terminology was good, fair, poor, and nil and wanted to know if UAL Flight 462 was reporting fair or poor on the runway. UAL Flight 462 replied that it was poor on the runway. UAL Flight 694 landed three minutes after UAL Flight 462 and reported good braking. This good braking action report was relayed to the Envoy Flight 3647 Canadair Regional Jet (CRJ) landing another five minutes later. The DAL Flight 1086 crew overheard conversation on the frequency of the poor braking action report. The flight crew had a discussion that they would be unable to land with a poor braking report and briefly discussed diverting to Albany, this

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[47] Airports Group Factual Report—Attachment 3—NTSB Interview Transcript, page 18
[48] Airports Group Factual Report—Attachment 3—NTSB Interview Transcript, page 27
[49] Airports Group Factual Report—Attachment 3 NTSB Interview Transcripts—Interview with Kevin Dauweiler, page 66

included a discussion on the fuel they had available. Subsequently, a good braking action report from a regional jet was relayed to DAL Flight 1086, and the crew overheard a good braking action report from the other United aircraft.

During the morning of March 5, 2015, LGA issued a NOTAM at 0738.[50] At 0557, the MAT weather service reported no snow accumulation. Over the next several hours, the snowfall rate was in a range of 0.4 to 0.7 inches per hour. This is considered heavy snowfall, according to the International Civil Aviation Organization (ICAO) Manual on Automatic Meteorological Observing Systems at Aerodromes section 6-2.[51] Visibility and prevailing snowfall rate was corroborated by interviewing the lead snow operator of the team assigned to accident runway. The lead operator stated that he could not see the accident aircraft as it rested post-accident from his position at taxiway DD due to prevailing visibility and not line-of-sight restrictions.

3.3 Continuous Runway Monitoring Requirement

In AC 150/5200-30C dated December 9, 2008, the FAA called for NOTAMS describing the changes in runway condition to be timely. This is the case for both worsening conditions due to weather conditions and improving conditions due to actions taken to mitigate such conditions. The AC further stated that the runway condition reports must be updated any time a change to the runway surface condition occurs. Changes that initiate updated reports include weather events, the application of chemicals or sand, or plowing or sweeping operations. The airport operators should not allow aircraft operations on such runways after such activities until a new runway condition report is issued reflecting the current surface condition(s) of affected runways.

During the snow event, LGA Airport did not use continuous friction measuring equipment (CFME) devices, which were purchased and stored at the airport due to nonuse and calibration issues. The use of CFME devices is recommended by the airport to monitor friction trends per AC 150-5300-30C. The airport's operations manager stated that he understood that the CFME could be used as a tool for snow removal trend analysis, but on the day of the accident they were evaluating the runway based on their observations and snowfall rate. This is in contradiction to LGA's Airport Certification Manual (ACM) and training videos,[52] which stated that LGA utilizes a CFME-type friction tester to conduct friction readings when conditions require trend analysis on a frozen or contaminated surface. The ACM also contained a letter of agreement (LOA)[53] with the LGA Air Traffic Control Tower (ATCT) stating that when it becomes apparent that conditions may result in degraded runway surface friction, Airport Operations may conduct friction assessments using whatever techniques the airport duty manager or snow coordinator deem appropriate, to include tactile feel, vehicle braking, and/or use of CFME.[54] If CFME is used, Airport

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[50] Airport Group Factual Report—Attachment 2, page 1

[51] Light snow is less than 1.0 mm (0.04 inches)/hour; moderate snow is between 1.0 and 5.0 mm/hour (0.2 inches/hour)

[52] Airports Group Factual Report—Attachment 8

[53] Airports Group Factual Report—Attachment 7, page 3

[54] Airports Group Factual Report, page 10

Operations will not report Mu values. During the morning leading up to the accident, the runways were only evaluated based on observations of snowfall rates, and no CFME device was used.

Figure 9: LGA Truck with Runway Friction Tester

The FAA Advisory Circular AC 150-5200-30C is too lax, as it allows a procedure using only braking action reports to qualify as “continuous monitoring” of the runway surface. Other methods are only recommended and not mandated. Use of friction monitoring equipment or decelerometers are only recommended actions for the airport.

In order to provide flight crews with the most current and accurate runway condition reports, it would be good practice to conduct a tactile inspection of the runway condition. This allows the airport operator to distinguish between wet snow or slush and dry snow. No provisions in AC 150-5200-30C require a tactile measurement of snow depths or condition, which allows the airport operator to estimate depths and conditions when issuing NOTAMs; this was admitted by the LGA airport operator as stated in interviews that they just leave “0.25-inch clutter” in every NOTAM issued, unless it gets deeper.

3.4 Post-Crash Friction Testing

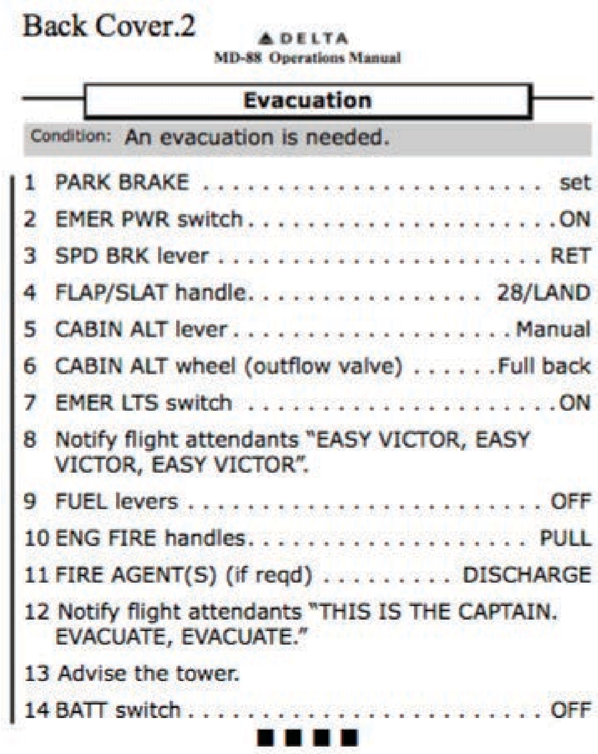
Delta Air Lines had requested that a post-crash friction measurement be conducted on Runway 13, which was not completed by the port authority. The airport operator did not comply with AC 150-5200-

30C,[55] or its own Snow Operations Training video guidance by not conducting a post-accident friction test for accident runway but instead completed a friction measurement for Runway 4-22, not the runway the accident actually occurred on.

4.0 Survival Factors

4.1 Post-Accident Crew Actions

According to the crew interviews, the flight crew noted that there was no power to the aircraft due to the engines having been shut down and the battery connections being severed during the accident sequence. The flight crew switched on emergency power and attempted to start the auxiliary power unit (APU) without success. The captain attempted to contact the cabin and determined that the public address (PA) and interphone were inoperative. He opened the cockpit door and established communications with the cabin crew. The captain stated that he instructed the flight attendant to assess the exits. He returned to his seat and ensured the evacuation checklist was completed.



Back Cover.2

▲DELTA
MD-88 Operations Manual

Evacuation

Condition: An evacuation is needed.

1 PARK BRAKE . . . . set
2 EMER PWR switch . . . . ON
3 SPD BRK lever . . . . RET
4 FLAP/SLAT handle. 28/LAND
5 CABIN ALT lever . . . . Manual
6 CABIN ALT wheel (outflow valve) . . . . . . Full back
7 EMER LTS switch . . . . ON
8 Notify flight attendants "EASY VICTOR, EASY VICTOR, EASY VICTOR".
9 FUEL levers . . . . OFF
10 ENG FIRE handles. PULL
11 FIRE AGENT(S) (if reqd) . . . . DISCHARGE
12 Notify flight attendants "THIS IS THE CAPTAIN. EVACUATE, EVACUATE."
13 Advise the tower.
14 BATT switch . . . . OFF

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Figure 10: Delta MD-88 Operations Manual, Evacuation Checklist

Normally, the cabin crew would communicate their assessment of the exits through the interphone. Because emergency power was unavailable to the communication system, the cabin crew had to walk

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[55] AC 150-5200-30C—Section 2-6 Subpart B and Section 5-3, Subpart B, Line 3

through the cabin and establish communication. One flight attendant stated that she attempted to use a megaphone, but it did not work.

The captain's point of contact was the forward flight attendant, and her only means of communications was the megaphone. So the captain said to evacuate through the right wing exits only on the FO's side right now, and the forward flight attendant initiated the evacuation.[56]

The condition of the aircraft and the communication system created a situation that was unusual for the flight and cabin crew. Therefore, the crewmembers had to use judgment and initiative to conduct a safe and orderly evacuation.

4.2 Passenger Conduct

As stated in the interviews with the flight attendants, there were several passengers using their cell phones during the post-accident period. Flight attendants expressed concern that the passengers could not hear important communications. Flight attendant 3 stated: "So I started to walk back to see if I could use my exit, the tailcone. That is when I realized everybody (120+ passengers) were talking on their cellphones. It was very loud. So I started shouting commands as I walked back to the aft tailcone. Get off your cellphones, you need to listen. We need to prepare for an evacuation, Get off your cellphones now!"[57] In addition, there were several passengers trying to retrieve their carry-on baggage during the evacuation. These actions by the passengers clearly interfered and delayed the evacuation, increasing potential hazards to passengers and the crew.

5.0 Changes Being Implemented by the FAA Due to the TALPA ARC

On March 5, 2015, the eastern United States experienced a significant snow storm with snowfall rates of up to 1.0 inches per hour. The NWS will issue a heavy snow warning when snowfall rates reach 4 inches per 12 hours or 0.33 inches per hour. In the hour leading up the accident, the snowfall rate was reported at 0.4 inches per hour. At 1651 UTC (1151 EST) the Marine Air Terminal (MAT) weather service reported a total of 3.4 inches of snow since beginning of the snowfall at 0657 EST and 0.7 inches of accumulation in the previous hour.

According to the dispatcher responsible for the flight planning, release, and flight following, the runway was only broomed and had not been treated with chemicals and there was 0.25 inches of snow on the runway.[58] The ATIS timestamped 1024 also stated that there was a 0.25 inches of snow on the runway observed at 1404Z. According to the Runway Condition Assessment Matrix (RCAM) included in the final report of the Takeoff and Landing Performance Assessment (TALPA) Aviation Rulemaking Committee (ARC) and the AC 25-32, any runway surface condition description with contamination of dry or wet

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[56] Operations Group Factual Report—Attachment 1—Interview Summaries, page 18

[57] Survival Factors Group Factual Report—Attachment 1—Flight Attendant Statements, page 5

[58] Meteorology Group Factual Report—Attachment 1, page 1

snow greater than one-eighth inch is correlated to medium braking action.[59] At the time of the accident this AC had not been published. The effective date of the AC was December 12, 2015.

As discussed in Section 1.1, the flight crew needed “good” braking action to land at LGA. If the same conditions existed today as the day of the accident based on the new TALPA AC, the flight crew of DAL 1086 would not have been allowed to land.

6.0 Conclusions

The NWS forecasted a major snowstorm for the Mid-Atlantic region with estimated snow totals of up to 8 inches. Snow had just begun in LGA at the time DAL Flight 1086 departed ATL. The aircraft was dispatched in accordance with FAR Part 121.195 dispatch requirements. This required the dispatcher to calculate landing performance based on wet runway condition at the destination airport. This did not require any calculations based on snow covered runway conditions. While this was in accordance with current regulations, this put the flight crew in a position where it is solely their responsibility to determine the required runway condition at the destination for landing the aircraft. The flight crew of DAL Flight 1086 determined early in their flight that they would need a braking action report of “good” in order to land the aircraft at LGA. Throughout the flight the flight crew requested updated field conditions reports to ensure that they have an accurate picture of the runway conditions prior to their approach.

The landing distance assessment the crew performed was based on “good” braking action as reported by preceding flights. While they were aware of a poor report from a United Airbus, they received two good braking action reports from the following aircraft, and another DAL MD-88 landed prior to them with no braking action report. This convinced the flight crew that it was safe to land the aircraft in the current conditions.

Both flightcrew members expected a cleared and chemically treated, wet runway based on the field condition reports they had received, but they found a snow covered runway. The FCTM stated that when landing on a slippery runway to “land a soon as possible.” The captain adjusted his aim point to land within the first 1,000 feet of the runway. Correlated FDR and performance data estimated the touchdown point at around 600 feet from the threshold. This placed the aircraft on the pier section of Runway 13, which had accumulated a layer of ice due to the reported weather conditions of freezing fog for the preceding 3 hours.

The aircraft touched down in the first section of the touchdown zone, which was earlier than on a normal flight. It is more common for aircraft to follow the glideslope to the glideslope/runway intercept point. The glideslope intercept point is close to 1,000 feet from the threshold, which is after the end of the pier. Therefore, DAL Flight 1086 spent a period of time during its initial rollout on an icy surface.

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[59] AC 25.32 Landing Performance Data for Time-of-Arrival Landing Performance Assessments—Table 2, page 14

This landing on an icy surface led to a delay in wheel spin-up, resulting in non-deployment of the auto spoilers. The FO deployed the spoilers manually, which without wheel spin-up only deployed the flight spoiler panels. Movement of the speedbrake handle activated the maximum auto brakes. Abnormal antiskid operation would be expected with low- to no-wheel spin-up accelerations on a low- to no-traction runway surface and delayed spoiler deployment at touchdown.[60]

Shortly after touchdown with the nose still in the air, the thrust reversers were deployed. Nose-strut compression (WOW) occurred at 11:02:19. Within about 4 seconds, the left engine EPR rose to a peak of 2.09 and the right engine EPR to 1.91. According to Boeing, rudder and vertical stabilizer blanking occurs when EPR settings exceed 1.6. The elevators moved to an almost complete trailing edge down position. This exceeded the amount of forward control column commanded by the flight crew. This elevator position reduced the downward force on the main gear, further limiting braking and cornering forces available and severely limited the longitudinal directional controllability of the aircraft.

The aircraft began to gradually yaw left; however, this rate increased rapidly. During this time, the aircraft remained within 5 feet of the runway centerline, based on ASR, essentially sliding down the runway track. As the FO recognized changes in heading, he called "come out of reverse" three times within two seconds. The captain immediately stowed the reversers. With the reversers stowed, rudder effectiveness was regained. After the reversers were stowed, the EPR settings were still at considerably high range, resulting in forward thrust, pushing the aircraft in the direction of its heading. Approximately 0.5 seconds later, a momentary increase in the right braking system pressure was recorded, consistent with application of manual braking; this action disengaged the auto brakes. With the wheels turning, cornering forces were restored. The captain applied right rudder, and the left yaw was arrested. The aircraft heading began to turn toward runway heading. Before the captain was able recover full control, the aircraft tracked off the runway surface. Once the aircraft departed the runway surface, the crew had very little control over the aircraft's direction and speed.

The pier's icy condition and the runway snow covered surface created a challenging environment, which reduced runway friction, contrary to the information the crew had received from dispatch and ATC, as reported by the airport operator. The CVR and the ACARS reports show that the crew continuously inquired about field condition reports in order to make a safe assessment to land at LGA. The ATIS current at the time of the accident, as well as field condition reports, stated that the runway was wet, sanded, and deiced with solid chemicals. Furthermore, it was reported that all runway field conditions were observed with 0.25 inches of wet snow. However, the last time it was chemically treated was at 0450. When the runway was broomed about 40 minutes prior to the accident, all applied chemicals were brushed off, and no chemicals were reapplied. The runway had never been sanded.

LGA was using continuous monitoring to assess field conditions in accordance with AC 150-5200-30C. Continuous monitoring allows the airport to use braking action reports by pilots as their sole method for evaluating runway surface condition. However, this method does not take in the variables of aircraft type or the pilot's perception of how effective the braking actually was.

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[60] NTSB Aircraft Accident Report—AAR-01/02, page 93

Eight minutes after brooming the runway, the first aircraft landed and reported braking action “poor on the runway” to LGA Tower. The snow coordinator overheard the remark and did not take action. In accordance with AC 150-5200-30C, no action was required until a second consecutive poor report is received. The Port Authority was required to provide updated field reports with changing conditions. Instead of providing new updated reports, the Port Authority used the same “canned” report, which included 0.25 inches of wet snow on the runway and that the runway was sanded and chemically treated. Pilots have to rely on accurate condition reporting to make an assessment of the landing conditions for the time of arrival.

The Delta dispatcher’s statement showed he had overheard a radio conversation between LGA Tower and the Port Authority, just prior to DAL Flight 1086’s approach, that the runways were not sanded or chemically treated and that there was still 0.25 inches of snow on the runway. This information was not relayed to the flight crew.

AC 150-5200-30C, highly suggested CFME to be used by the airport for trend monitoring of a surface condition worse than dry. The airport chose not to use this equipment during this snow event. CFME equipment provides accurate trend reports that can only be used by the airport to determine if a runway needs clearing. Additionally, the airport did not comply with AC 150-5200-30C, which requires a post-accident friction measurement of the accident runway.

ALPA agrees with the NTSB Performance Study conclusion, which states: “The data was incomplete or the effects of these forces on the aircraft were not measured and/or accurately modeled for the exact contribution of each to be determined. What data was available did not make any single event or environmental factor seem likely on its own to be able to impart the yawing moment experienced by the accident aircraft. It is likely that a combination of asymmetric thrust, crosswind, and runway friction caused the aircraft to deviate from the runway heading.” There was no single event that caused this accident, but a series of factors all played a role.

7.0 Findings:

1. The flight was operated as a 14 CFR Part 121 Scheduled, Domestic flight.
2. The flight crew was properly certificated and qualified in accordance with applicable federal regulations.
3. The airplane was properly certified, equipped, and maintained in accordance with federal regulations.
4. The aircraft was legally dispatched to an airport where the forecasted weather made a safe landing improbable.
5. The aircraft landed within 600 feet of the runway threshold on the pier, which was susceptible to freezing before the rest of the asphalt runway surface.
6. The pier section of the runway had accumulated ice.
7. Auto spoilers did not deploy automatically because main wheel spin-up was delayed or did not occur.
8. Abnormal antiskid operation would be expected with low- to no-wheel spin-up accelerations on a low- to no-traction runway surface and delayed spoiler deployment at touchdown.
9. Thrust reversers were deployed with maximum EPR reaching 2.09 on the left and 1.91 on the right.
10. The elevator trailing edge was in the down position for a good portion of the landing roll, which reduced the downward force on the main landing gear.
11. NOTAMs and ATIS stated that the runway was covered with 0.25 inches of snow.
12. According to the new TALPA guidance, 0.25 inches of snow would be equivalent to medium braking action.
13. Runways were chemically treated at 0450, yet in all of the following NOTAMs and ATIS, the remark for chemically treated runways remained.
14. UAL 462 reported “poor” braking action.
15. Port Authority did not act upon “poor” braking action report and did not assess or chemically treat the runway, but was not required to.
16. Port Authority only assessed the condition of the runway using the snowfall rate and pilot reports.
17. FAA allows the continuous friction measuring requirement to be fulfilled by only using PIREPs.

18. No post-crash friction measurement was conducted on Runway 13, despite having been requested by Delta Air Line and required AC 150-5200-30C.
19. LGA does not use any CFME to monitor runway friction and runway condition.
20. No tactile inspection of the runway was conducted.
21. There was no single event or environmental factor that seems likely on its own to be able to impart the yawing moment experienced by the accident aircraft.
22. It is likely that a combination of asymmetric thrust, crosswind, and runway friction caused the aircraft to deviate from the runway heading.
23. The usage of cellphones and retrieval of personal belongings by some passengers interfered with the evacuation.

8.0 Recommendations:

To the FAA:

1. Require PIREPS with “less than good” braking reports to be relayed to the following aircraft landing on the same runway until a runway assessment can be completed by the airport
2. Require actual continuous runway condition monitoring (AC 150-5200-30C) and not only relying on pilot reporting or assessment using snowfall rates.
3. Runway condition reports should be in accordance with recommendations from Takeoff and Landing Performance Assessment (TALPA) Aviation Rulemaking Committee (ARC).
4. Require tactile inspection of runways during winter weather events, as this provides valuable feedback to flight crew as to the type of contamination that can be expected on a runway.
5. Require POIs of all operators of MD-80 series aircrafts to review and determine that these operators’ flight manuals and training programs contain information on the decrease in rudder effectiveness during the use of reverse-thrust power in excess of idle reverse and higher.
6. Require all operators of MD-80 series aircraft to require a callout if reverse-thrust power exceeds the operators’ specific engine pressure ratio settings.
7. Require all 14 CFR Part 121 operators of thrust reverser-equipped aircraft to incorporate a procedure requiring the pilot monitoring to check and confirm the thrust-reverser status immediately after touchdown on all landings.
8. Develop and issue formal guidance regarding standards and guidelines for the development, delivery, and interpretation of runway surface condition reports.
9. Require establishment of a minimum standard for 14 CFR Part 121 operators to use in correlating an aircraft’s braking ability to braking action reports and runway contaminant type and depth reports for runway surface conditions worse than bare and dry.
10. Require all 14 CFR Part 139 certificated airport operators to include in their airport’s snow and ice control plan absolute criteria for type and depth of contamination and runway friction assessments that, when met, would trigger immediate closure of the affected runway to air carrier operations. Friction assessments should be based on pilot braking action reports, values obtained from ground friction measuring equipment, and estimates provided by airport ground personnel.
11. Require that initial and recurrent air traffic controller training programs stress the importance of transmitting all known contaminated runway condition information to departing and arriving flights, that a “medium” or “poor” braking action report from a pilot may indicate conditions

that are hazardous for different aircrafts, and that departing and arriving pilots should be informed when no recent landing by a comparable aircraft has been made.

12. Require that controllers disseminate "poor" and "nil" braking action reports promptly to airport management and to all departing and arriving flights until airport management reports that the braking action is "good."
13. Require dispatchers to provide all updated field conditions during contaminated runway operations.
14. Require that prior to dispatch, suitable runways should be evaluated for landing performance based on forecasted surface conditions at the time of arrival, including forecasted snowfall and accumulation rates.

To Delta Air Lines:

1. Eliminate conflicting guidance in the manuals related to landing on contaminated runways.
2. Include all pertinent information and operating guidance for slippery and contaminated runway operation in one section of a manual.

To Delta Air Lines and Boeing:

1. Provide effective and objective guidance for specific aircraft operations related to landing on contaminated runways.

To Boeing:

1. Require the use of idle reverse as the maximum reverse power for MD-80 series aircraft under contaminated runway conditions, except in an emergency in which directional control can be sacrificed for decreased stopping distance.