BOEING®

Submission to the

National Transportation Safety Board

for the

American Airlines 1420 Little Rock
and
American Airlines 9503 Palm Springs

Investigations

From The Boeing Company

June 25, 2001

INTRODUCTION

On June 1, 1999, at 2351 central daylight time, a Boeing MD-82, N215AA, operated by American Airlines as Flight 1420, a regularly scheduled passenger flight from Dallas–Fort Worth to Little Rock, Arkansas (LIT), overran runway 4R at LIT, went down an embankment, and impacted approach light structures. Thunderstorms and heavy rain were reported in the area at the time of the accident. The accident resulted in 11 fatalities, including the captain, and numerous injuries among the 145 passengers and crew aboard the flight. The airplane was destroyed.

A second event occurred on February 16, 2000 at 0708 pacific standard time when a Boeing MD-83, N597AA, operated by American Airlines as Flight 9503, a repositioning flight from Los Angeles to Palm Springs (PSP), departed the paved surface of runway 13R at PSP. Rain was reported in the area before the incident. There were no injuries, and the airplane sustained minor damage.

Submission Abstract

- The Boeing Company, as the airplane's manufacturer, is acting as a technical and operational advisor to the National Transportation Safety Board (NTSB) in these investigations.
- The conclusions presented in this submission are based on factual information, Boeing expertise, the use of analytical tools, and a methodical investigation process.
- In both events, the spoilers were not deployed after touchdown, causing reduced weight on the landing gear which resulted in decreased wheel braking ability, decreased cornering ability, and increased stopping distance.
- In both events, the autospoiler system operated normally and would have deployed the spoilers had the speedbrake handle been armed at touchdown.
- In the Little Rock accident, the available runway length would have been sufficient had the spoilers been deployed after touchdown.
- In both events, the deceleration rates recorded on the flight data recorder (FDR) indicate that wheel braking occurred and that runway friction levels were typical for a wet runway.
- In both events, reverse thrust above 1.3 engine pressure ratio (EPR) resulted in decreased directional control authority.
- In the Little Rock accident, the design of the aircraft interior contributed to the survival of 134 passengers and crew.

Boeing Assistance With These Investigations

The National Transportation Safety Board (NTSB) led the investigations into the Little Rock accident and Palm Springs incident. Assisting the NTSB in their investigations were the Federal Aviation Administration (FAA), American Airlines (AA), the Allied Pilots Association (APA), the Association of Professional Flight Attendants (APFA), the National Air Traffic Controllers Association (NATCA), Little Rock National Airport, Boeing, and other designated parties.

As the manufacturer of the MD-80 series airplanes, Boeing's specific role in these investigations has been to:

- Provide technical information regarding the airplane design and operation to assist the NTSB's Performance, Systems, Operations, and Survival Factors groups.
- Assist the NTSB with airplane performance calculations.
- Provide expert witness testimony at the NTSB Public Hearing in Little Rock in January 2000.

Furthermore, the NTSB has requested that all parties submit proposed findings to be drawn from the evidence revealed during the course of both investigations.

Boeing has responded to the NTSB request with this document, which:

- Provides an assessment of the evidence and other pertinent data.
- Identifies knowledge gained from the investigations and related activities.
- Describes the actions taken by Boeing to enhance the safety of the in-service fleet.

Evidence Assessment

The Boeing assessment of the evidence is based upon observations of the wreckage and accident site, post-event examination of airplane systems and components, the flight and radar data, and cockpit voice recorder (CVR) information.

Braking Performance and Ground Spoiler Usage

The NTSB Performance Study for the Little Rock accident describes the trajectory of the airplane during the landing from just before touchdown to the point where the airplane came to rest. This trajectory was calculated using radar data, FDR data, tire marks, wreckage location, and CVR information. At the request of the NTSB, Boeing calculated the deceleration profile and stopping distance for various airplane configurations and runway conditions. The configuration and conditions that resulted in the best match with the FDR data was a landing on a wet runway with reverse thrust, delayed braking (to match the brake application recorded on the FDR), and no spoiler deployment.

The study indicated that the lack of spoiler deployment after touchdown was the most significant factor in both the reduced braking performance and the diminished cornering capability on the runway. The study also indicated that wheel braking did occur, as reverse thrust and aerodynamic drag were insufficient to cause the recorded deceleration

profile. The calculated wheel braking force was consistent with runway friction levels typical of a wet runway considering the reduced weight on the gear because of the lack of spoiler deployment.[1]

A similar performance study of the Palm Springs event reached the same conclusion. Taking into account the position of spoilers and use of brakes and reverse thrust as recorded on the FDR during the landing, the NTSB study concluded that:

> The deceleration of the airplane is also consistent with the expected performance of the airplane given the lack of spoiler deployment. Specifically, the braking performance of the airplane is consistent with the vertical loads on the landing gear and nominal wet runway friction coefficients.[2]

In both the Little Rock and Palm Springs events, the airplanes' spoilers were not deployed during the landing rollout. The spoilers are designed to reduce the lift on the wing, placing more weight on the landing gear and providing additional aerodynamic drag. For any given runway friction condition, the amount of braking and cornering force available is directly proportional to the weight on the landing gear. Therefore, rapid extension of the spoilers is essential to developing maximum braking, cornering, and drag forces at high speeds.[3] As noted in the NTSB performance studies, the stopping distances would have been significantly reduced and cornering ability significantly enhanced if the spoilers had been used. Indeed, in the Little Rock accident, the available runway length would have been sufficient to stop the airplane had the spoilers been deployed after touchdown.

Autospoiler System

MD-80 series airplanes are equipped with an autospoiler system to automatically deploy the spoilers just after touchdown. The autospoiler system contains an actuator that operates on every landing but will only deploy the spoilers if the spoiler handle is in the ARM position. Boeing recommends that flight crews arm the autospoiler system by moving the spoiler handle to the ARM position in the "Before Landing" checklist.[4] Because of the importance of spoiler deployment, Boeing recommends that flight crews monitor spoiler deployment during touchdown and be prepared to manually deploy the spoilers if not deployed by the automatic system.[5]

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[1] NTSB Performance Group Chairman's Aircraft Performance Study (Little Rock), Dec. 18, 2000.
[2] NTSB Performance Group Chairman's Aircraft Performance Study (Palm Springs), May 17, 2001.
[3] For more information, see "Landing On Slippery Runways," *Airliner Magazine* (Boeing), Oct-Dec 1992, pp. 9-18; Little Rock Public Hearing Exhibit 13C *MD-80 Aircraft Performance*; and Twin Jet *Flight Crew Newsletter,* May 1995 (McDonnell Douglas).
[4] Boeing MD-80 Flight Crew Operating Manual, volume II, section 2, 1-40-0, page 6.
[5] Boeing MD-80 Flight Crew Operating Manual, volume II, section 2, 1-30-0, page 57, Landing Roll Expanded Procedures contains the following note: "If SPOILER lever does not move aft or does not remain at EXT position, PNF call, 'No Spoilers,' PF move lever aft to full extend position and up to latched position."

In both events, the autospoiler system was examined, and no faults were found that would prevent spoiler deployment.[6] [7] The NTSB found that the operation of the autospoiler actuator produces an identifiable sound that is recorded by the CVR whether or not the handle is armed. The same sound is evident on the CVR recordings of both the Little Rock and Palm Springs events, indicating that the autospoiler actuator operated in both cases.[8]

The evidence shows that the spoiler handle was not armed at touchdown in either event. In the Little Rock accident, the CVR contains no evidence to suggest that the spoilers were armed before touchdown.[9] In the Palm Springs event, the CVR suggests that the crew did arm the spoiler handle during the approach, but does not suggest how or why the handle subsequently became disarmed before touchdown.[10] Boeing analyzed all known failure conditions and could find no evidence of a failure that would result in the spoiler handle moving from the arm to the disarm position. In both events, there is no evidence that the flight crews monitored the spoiler deployment or attempted to manually deploy the spoilers after touchdown.

Additional Autospoiler System Considerations

If the flight crew decides to abort a landing and perform a go-around after the spoilers have deployed, the act of advancing the throttles will automatically "knock down" the spoiler handle, causing the spoilers to retract. If a landing is performed with the throttles set to an unusually high thrust level, the spoiler knockdown feature will cause the spoilers to partially deploy and then almost immediately retract. When knockdown events occur, the rapid up and down motion of the spoilers is recorded on the FDR.[7] [11] No evidence of a knockdown event was found in the FDR data for either Little Rock or Palm Springs. In addition, the engine thrust levels recorded during both events were below the level expected to trigger a knockdown.

Directional Control

Directional control during landing rollout is provided by two different forces: cornering force generated by the tires in contact with the runway and aerodynamic force generated by the vertical stabilizer and rudder. Any wheel that is not traveling straight ahead will generate a cornering force to correct the resulting tire skid. Like braking force, cornering force is generated by friction between the tire and the runway and is equally affected by the weight on the landing gear. Therefore, deploying the spoilers after touchdown results in significantly increased cornering force in addition to improved braking.

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[6] NTSB System Group Chairman's Factual Report (Little Rock), Nov. 5, 1999.
[7] NTSB System Group Chairman's Factual Report (Palm Springs), March 9, 2001.
[8] NTSB Specialist's Sound Spectrum Study - Cockpit Voice Recorder, Dec. 11, 2000.
[9] NTSB Cockpit Voice Recorder Group Chairman's Factual Report (Little Rock), Dec. 12, 2001.
[10] NTSB Cockpit Voice Recorder Group Chairman's Factual Report (Palm Springs), Jan. 21, 2001.
[11] NTSB Memorandum "Readout of flight data recorder data for two American Airlines MD-82 airplane autospoiler knockdown events," May 30, 2001.

The aerodynamic forces that affect directional control are generated by airflow over the vertical stabilizer and rudder. On the MD-80 series airplanes, the thrust reversers affect the airflow near the vertical stabilizer. Consequently, reverse thrust above 1.3 EPR can result in diminished rudder and vertical stabilizer effectiveness and thus reduce directional control authority. Boeing recommends that reverse thrust be limited to 1.3 EPR when landing on slippery or contaminated runways.[12] In both the Little Rock accident and Palm Springs event, reverse thrust usage at levels above 1.3 EPR was concurrent with directional control difficulties.

As noted in the NTSB Performance Study for Palm Springs,

> The directional control problems evident in the airplane's trajectory are not unexpected given the known deterioration of rudder effectiveness in reverse thrust at EPR levels above 1.3, and the lack of gear cornering and differential braking effectiveness resulting from the light loads on the gear.[13]

Survival Factors

In the Little Rock accident, the collision of the aircraft with the concrete and steel approach light and catwalk structure at the end of the runway created forces that exceeded the design criteria for the aircraft interior. The NTSB determined that 9 of the 11 occupants who died were seated adjacent to the several points of impact with the approach light structure. The remaining two fatalities died of thermal injuries or smoke inhalation during the evacuation. A complete examination was conducted of the passenger and crew seats and seat belts, emergency lights, escape systems, emergency equipment, overhead stowage bins, and other systems. The examination found that these systems contributed to the survival of 134 passengers and crew by restraining and protecting them from the forces of the collision and by allowing them sufficient time to escape from the wreckage.[14]

Wet Runway Tire Marks

In both the Little Rock and Palm Springs events, tire marks of the subject airplanes were found on the runways. In some places, the marks were black in color as would be expected when rubber is transferred from the tire to the runway. In other places, the tire marks were lighter than the surrounding areas on the runway and gave the appearance that the tires were cleaning the surface of the runway. The lighter marks were compared to other examples of lighter tire marks in the hope of determining what braking conditions (e.g., rolling, skidding, hydroplaning) existed at the time of their creation.

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[12] Boeing MD-80 Flight Crew Operating Manual, volume. II, section 2, 1-30-0, page 57, Landing Roll Expanded Procedures contains the following note: "On wet or contaminated runways and without intermediate Reverse Thrust Detent installed, reverse thrust of no more than 1.3 EPR should be used, except in an emergency."

[13] NTSB Performance Group Chairman's Aircraft Performance Study (Palm Springs), May 17, 2001.

[14] NTSB Survival Factors Group Chairman's Factual Report, Dec. 1, 1999.

Very similar or identical light tire marks have been found on wet runways and taxiways under the following conditions:

- Rolling tires subject to braking and cornering forces.[15]
- Locked wheels resulting in tires that were severely flat spotted and blown.[16]
- Rolling tires subject to maximum antiskid braking forces but no cornering forces.[17]
- Rolling tires during taxi and takeoff that were not subject to braking forces.[18]

In addition, where light marks are noted during accident investigations, there are typically many similar light marks from other airplanes reporting no difficulties on the same runway at nearly the same time as the accident airplanes. In a separate event, a DC-9 that overran the runway at Reynosa, Mexico on October 6, 2000,[19] left no visible runway marks. Available evidence indicates that the airplane experienced dynamic hydroplaning after touching down at approximately V_{ref}+20 on a very wet, ungrooved asphalt runway.

The above examples demonstrate that light tire marks can be created by a variety of phenomena and that other evidence must be assessed to determine what conditions actually existed. In both the Little Rock and Palm Springs events, the FDR recorded deceleration rates consistent with braking on wet runways at the time the light tire marks were created.

Knowledge Gained During the Investigations

Based on the findings described above, Boeing believes that the evidence supports the following conclusions for both the Little Rock and Palm Springs events:

- The autospoiler system functioned normally during the landing sequence and would have deployed the spoilers had the speedbrake handle been armed at touchdown.
- The brake system functioned normally during the landing rollout and provided braking forces consistent with wet runway conditions and low weight on the landing gear. Weight on the landing gear was low because the spoilers were not deployed.
- The use of reverse thrust above 1.3 EPR reduced the directional control authority and contributed to the directional control problems.
- Runway surface markings from tires in contact with a wet runway surface can be very difficult to attribute to a specific condition (e.g., rolling, skidding, hydroplaning) without supporting physical and/or flight recorder evidence.

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[15] DC-10 at Dallas-Fort Worth - DFW, 14 April 1993, NTSB/AAR-94/01.
[16] MD-83 at Bogotá, Colombia, Sept. 30, 2000.
[17] MD-11 at Subic Bay, Philippine Islands, Oct. 17, 1999. The NTSB, the FAA, and Boeing are assisting this ongoing Philippine investigation.
[18] 747-400 at Taipei, Taiwan, October 31, 2000. The NTSB, the FAA, and Boeing are assisting this ongoing Taiwanese investigation.
[19] The NTSB, the FAA, and Boeing are assisting this ongoing Mexican investigation.

Boeing believes that the evidence supports the following conclusions for the Little Rock accident:

- The interior systems (e.g., seats, emergency lighting, overhead bag racks) contributed to the survival of 134 passengers and crew following the several impacts with concrete and steel approach light structures.
- Structures near runway overrun areas should be designed so that minimal damage is inflicted to airplanes that are unable to stop on the runway surface.

Boeing Actions

As a result of these investigations, Boeing has:

- Issued advisory updates of the investigation's progress to all operators.[20]
- Suggested that operators review with their flight crews selected Boeing Flight Operations All Operators Letters, Flight Operations Bulletins, Twin Jet Flight Crew Newsletters, and the appropriate sections of the Flight Crew Operating Manuals (FCOMs) that address crosswind landings on slippery runways.[21]
- Advised the NTSB, the parties to the investigation, and the public of the importance of ensuring spoiler deployment after touchdown via our witnesses' testimony at the February 2000 Public Hearing for the Little Rock accident.

Summary

As documented in the various NTSB factual reports and studies, both investigations underscore the importance of ensuring that ground spoilers deploy after landing to provide maximum braking performance and directional control authority, especially on wet or contaminated runways. Flight crews must be made aware of the need to ensure that ground spoilers are deployed after landing, especially on slippery and/or contaminated runways, and must be prepared to deploy the spoilers manually if required.

Both investigations also demonstrate the effect of reverse thrust levels above 1.3 EPR on directional control and underscore the need for MD-80 flight crews to limit reverse thrust to approximately 1.3 EPR when landing on wet or contaminated runways.

[20] Boeing All-Operator Messages B-H200-AB-353-ASI dated June 2, 1999 and B-H200-AB-354-ASI, dated June 14, 1999.
[21] Boeing All-Operator Message B-H200-AB-411-ASI, dated 28 Sept 2000.