Runway overrun, Caribbean Atlantic Airlines, Inc., Douglas DC-9-31, N938PR, Harry S. Truman Airport, Charlotte Amalie, St. Thomas, Virgin Islands, August 12, 1969

Micro-summary: **This Douglas DC-9-31 overran the runway on landing.**

Event Date: **1969-08-12 at 1409 AST**

Investigative Body: **National Transportation Safety Board (NTSB), USA**

Investigative Body's Web Site: **http://www.ntsb.gov/**

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SA-None File No. 1-0046

AIRCRAFT ACCIDENT REPORT

CARIBBEAN ATLANTIC AIRLINES, INC.
DOUGLAS DC-9-31, N938PR
HARRY S. TRUMAN AIRPORT
CHARLOTTE AMALIE, ST.THOMAS, VIRGIN ISLANDS
AUGUST 12, 1969

Adopted: SEPTEMBER 16, 1970

NATIONAL TRANSPORTATION SAFETY BOARD
Bureau of Aviation Safety
Washington, D. C. 20591

CARIBBEAN ATLANTIC AIRLINES, INC.
DOUGLAS DC-9-31, N938PR
HARRY S TRUMAN AIRPORT
CHARLOTTE AMALIE, ST. THOMAS, VIRGIN ISLANDS
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File No. 1-0046

NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
AIRCRAFT ACCIDENT REPORT

Adopted: September 16, 1970

Caribbean Atlantic Airlines, Inc.
Douglas DC-9-31, N938PR
Harry S Truman Airport
Charlotte Amalie, St. Thomas, Virgin Islands,
August 12, 1969

SYNOPSIS

Caribbean Atlantic Airlines, Inc. (Caribair), Flight 340, a Douglas DC-9-31, N938PR, was involved in a landing accident at 1409 A.s.t.*, on August 12, 1969, at Harry S Truman Airport, Charlotte Amalie, St. Thomas, Virgin Islands. The aircraft, on its landing rollout, continued 323 feet beyond the far end of Runway 9, and came to rest in an automobile repair shop, after striking several vehicles. There were 114 passengers aboard and a crew of five. Evacuation of the aircraft was orderly, with one passenger sustaining minor injuries. Three occupants of the ground vehicles, which were struck by the aircraft after it left the runway, were seriously injured and one was slightly injured.

The weather in the vicinity of the airport had been characterized by intermittent rain showers from early in the morning through the time of the accident, and a total of 2.74 inches of rain was recorded for the 24-hour period. The existence of a considerable amount of standing water on the runway was corroborated by witnesses who stated that the aircraft was churning up heavy water spray on its rollout and did not appear to be decelerating very rapidly.

Near the end of the runway, the aircraft was observed to be fishtailing which was accompanied by loud sounds of engine reversing and associated popping noises. White tire streaks, typical of those observed in cases of known hydroplaning, were observed in the last 1,400 feet of runway, leading off the runway into the aircraft tire tracks in the wet, sodded area between the runway and the street.

PROBABLE CAUSE

The Board determines that the probable cause of this accident was the loss of effective braking action caused by dynamic hydroplaning of the landing gear wheels on a wet/flooded runway. Contributing factors were a higher-than-normal touchdown speed and the location of the airport and its topography which permitted excess levels of water to accumulate on the runway.

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* All times used herein are Atlantic standard (A.s.t.) based on the 24-hour clock.

The Board has recommended to the Federal Aviation Administration that it conduct further research and studies in order to develop more definitive wet runway criteria than currently exists. The Virgin Island Airport Authority has had this runway grooved as a result of this accident and subsequent investigative findings.

1. INVESTIGATION

1.1 History of the Flight

Caribbean Atlantic Airlines, Inc. (Caribair), Flight 340, of August 12, 1969, was a regularly scheduled flight originating in San Juan, Puerto Rico, with a scheduled landing at St. Thomas, V. I., and return to San Juan. The aircraft used on this flight was a Douglas DC-9-31, N938PR. On August 12, 1969, at 1245, the flight departed routinely from San Juan, Puerto Rico, on an Instrument Flight Rules (IFR) flight plan to St. Thomas, V. I. At approximately 1354, St. Thomas Approach Control cleared Flight 340 for an approach to Harry S Truman Airport, giving it the station altimeter setting of 29.91 inches and requesting that the flight report out of 5,000 and 4,000 feet. On reporting out of 4,000 feet, the crew asked Approach Control if it was raining at the field. Approach Control replied that there was presently a light rain shower and that the runway was wet. At 1359, the flight reported it was south of the airport in visual flight conditions and was cancelling its instrument flight plan. The wind was given at this time as 160° at 4 knots. At 1401, the pilot stated he was going to hold southeast of the field at 1,300 feet to wait for the rain showers to clear the west end of the airport and approach path to Runway 9.

At 1407, the tower informed other traffic that the DC-9 was turning final 1 mile out and gave the wind as 120° at 5 knots.

The crew reported that the aircraft had operated satisfactorily until the time of the landing; copilot Gonzalez was controlling the aircraft at the time of the landing; the landing checklist had been completed; the antiskid brake system switch was on; the landing flaps were fully extended (50°); the wing spoilers were armed; the approach speed was reference speed (124 knots indicated) plus 10 knots; and the initial touchdown was on the main landing gear, approximately 800 feet from the approach end of the runway. The crew indicated that they could feel the wing spoiler deployment as a result of the aircraft's squatting on its landing gear struts. However, application of reverse thrust and pressure on the brake pedals did not slow the aircraft as was expected. Full reverse thrust, stated by the captain as 2.0 engine pressure ratio (EPR), was applied by the copilot with assistance by the captain. Furthermore, according to the crew, additional pressure on the brakes by the copilot, with assistance by the captain, failed to slow the aircraft. The crew continued application of maximum available reverse thrust and pressure on the brake pedals until the aircraft came to rest. The flight recorder tape indicated that the initial touchdown was at 135 knots indicated airspeed (KIAS).

The crew did not attempt to open the aft fuselage stair exit. With the exception of the copilot who used the right cockpit exit, all personnel on board evacuated the aircraft over the wings, using the four overwing emergency exits.

Witness and crew statements varied considerably as to the aircraft touchdown point, placing it somewhere between 800 and 1,800 feet beyond the threshold of Runway 9. The local Federal Aviation Administration (FAA) controller stated that he observed the aircraft touch down approximately 1,800 feet from the approach end of Runway 9. Two witnesses, employed by Caribair and situated at the Caribair Terminal adjacent to the runway, stated that there was considerable water on the runway, and that a small twin-engine aircraft, which had landed just prior to the DC-9, was observed to have been almost engulfed by water spray.

The airport fire chief (who was outside the fire department, located on the north side of Runway 9, approximately two-thirds of the distance from the approach end of the runway) said that it was raining when the DC-9 landed, and observed that the aircraft was not decelerating after touchdown, which prompted the "scramble" of emergency equipment. The fire chief observed that water on the runway, at an estimated depth of one-half of an inch, was draining to the north side. The DC-9 also was observed to be churning up considerable water spray and was noted to be fishtailing near the far end of the runway. Sounds of heavy engine reversing were heard. Some passengers reported that the landing seemed normal; that some rain was falling; that loud engine reversing noise and later engine popping sounds were heard; and that the aircraft did not seem to be slowing down as fast as in other jet landings they had experienced. Several passengers and four ground witnesses stated the aircraft bounced after initial touchdown.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	3
Minor	0	1	1
None	5	113	

The most serious injury, which resulted in a subsequent leg amputation, was incurred by an occupant trapped in a damaged automobile.

1.3 Damage to Aircraft

The aircraft incurred substantial damage to the nose landing gear, nose section, wings, and fuselage.

1.4 Other Damage

The aircraft tore out a 50-foot section of chain-link fence at the airport boundary. The ground vehicles struck by the aircraft sustained considerable damage, ranging from substantial to total loss. The repair shop structure, into which the nose of the aircraft had penetrated, also was substantially damaged.

1.5 Crew Information

The crew of Flight 340 was properly certificated and qualified to conduct the flight. (For detailed information concerning the crew, see Appendix B.)

1.6 Aircraft Information

N938PR, a Douglas DC-9-31, Serial No. 47098, was manufactured in April 1967. The total time on the aircraft was 4395:09 hours.

An examination of the maintenance records for N938PR disclosed that the aircraft had been maintained in accordance with Caribair and FAA procedures and regulations. Required inspections had been accomplished and nonroutine items had received corrective action. The maintenance records on March 19, 1969, reflected two malfunctions of the antiskid brake system. The first discrepancy noted that there were no brakes on taxi-out, although the pressure and fluid were "OKAY," antiskid switch "ON." However, with antiskid switch "OFF," brakes worked "OKAY." A new antiskid control box out of stock was installed, replacing antiskid control box, Part No. 42-139-2A, Serial No. 409, but did not correct the problem. Another control box was then installed and this action was signed off as correcting the problem. The same discrepancy occurred on the next landing at St. Croix, when the brakes were again inoperative with the antiskid on. At this time, relay P/N 9 74-3642 was replaced and there were no further discrepancies of a similar nature reported. The antiskid control box S/N 409 was thus considered serviceable and was reinstalled in N938PR on the following day and operated satisfactorily during the ensuing period.

N938PR was powered with two Pratt & Whitney Model JT8D-7 engines, both of which remained attached to the aircraft. Disassembly and examination of the engines, as well as crew and witness testimony, revealed no evidence of preaccident failure or malfunction.

The maximum certificated landing weight for N938PR on a wet runway, with antiskid operating, at Harry S Truman Airport, St. Thomas, V. I., was 94,400 pounds, requiring the full 5,150 feet of Runway 9. The calculated landing weight for N938PR at the time of the accident was 91,920 pounds, which requires a wet runway length of about 5,050 feet. The computed center of gravity (c.g.) was 16 percent MAC, which was well within the certificated limits.

1.7 Meteorological Information

1350 - 1,500 feet scattered clouds, estimated broken clouds at 6,000 feet, high cirroform overcast, visibility 15 miles, very light rain showers, temperature 81°F., dew point 78°F., wind 120° at 8 knots, altimeter 29.91.

Remarks: rain showers of unknown intensity to the west and south of the field.

1415 - estimated 1,500 feet broken cloud layer, 6,000 feet broken cloud layer, high cirroform overcast, visibility 15 miles, verylight rain showers, temperature 78°F., dew point 76°F., wind 320° at 5 knots, altimeter setting 29.91.

The 1415 observation was taken as a result of the accident. The weather in the vicinity of the airport had been characterized by rain showers since early in the morning through the time of the accident. There was a total of 2.74 inches of rainfall measured at the airport during this 24-hour period (0001 to 2400 on August 12, 1970), with 1.41 inches falling from 0800 to 2000. Harry S Truman Airport receives an average of 46 inches of rain a year. All the reported weather observations (taken at 10 minutes before the hour) showed light to moderate rain occurring throughout the day from 0650 to 2250. There is no method available to tower personnel to measure amounts of standing water on the runway.

1.8 Aids to Navigation

The Harry S Truman Airport is served by a VOR (OMNI) range facility, operating on a frequency of 108.6 MHz, with a commensurate instrument VOR approach procedure to the airport.

1.9 Communications

Communications between the aircraft and St. Thomas Approach Control and Tower were normal, with no indication that there were any difficulties being experienced by N938PR.

1.10 Aerodrome and Ground Facilities

Harry S Truman Airport was built by U. S. Navy during World War II in the early forties. The facility was turned over to the Port Authority at Charlotte Amalie for municipal use in 1948. The airport has one runway, oriented east and west, which consists of an ungrooved bituminous-surfaced pavement and a 500-foot concrete extension, for a total length of 5,150 feet. The runway is 200 feet wide for the first 4,650 feet, then narrows to a 100 feet in width for the last 500 feet, which abuts and extends the northern portion of the 100-foot width. Runway 9 does not have a crown in the center for drainage but does have a 1-percent transverse slope south to north. The Airport Master Plan drawing (dtd. 11/27/68) shows the runway as having an elevation of 10.1 feet at the east end, sloping to an elevation of 6.9 feet near the middle, and raising up to 14.1 feet at the western end. The airport is located about 2½ miles to the west of Charlotte Amalie on the south shore of St. Thomas. This location is essentially the only sizable, low, flat area on the island, and it is almost completely surrounded by higher ground on all sides.

The VASI bars are located 550 feet and 1,050 feet, respectively, from the approach end of the runway, giving a threshold crossing altitude of about 35 feet. The visual aiming point is 800 feet down the runway from the threshold. Based on a 2.5° glidepath angle, the touchdown point for DC-9 aircraft is between 400 to 500 feet from the runway threshold. At a 2.5° angle, the rate of descent is computed to be 545 feet per minute at 125 knots. Prior to January 1970, the St. Thomas VASI system was the property of the Virgin Island Authority which operates the Harry S Truman Airport. The ownership, operation, maintenance, logistic support, and operational responsibility has been transferred to the FAA as of January 18, 1970.

St. Thomas has a yearly temperature variation from 70° to 89°F. The yearly fluctuation of relative humidity is from 64 to 84 percent, and the average annual rainfall is about 46 inches. The airport site, at an elevation of approximately 11 feet has been known to become inundated after heavy rainfalls. In 1951, using the airstrip as a catchment area, a drainage collection system was constructed along the north side of the runway. Also at this time, water treatment facilities were installed on the north side of the airstrip near the easterly end. Three other water catchment areas are located in close proximity to the airport. Two of these are south of the airport, one near the control tower and south of the easterly runway extension. The third catchment area is located approximately 800 feet north of the runway, opposite the control tower.

The FAA certificated Caribair to operate DC-9-31 aircraft into Harry S Truman Airport utilizing the available runway. Runway 9 at Harry S Truman Airport was specified as having an effective length of 5,150 feet and an effective width of 100 feet. The FAA authorized Caribair to land DC-9-31 aircraft on Runway 9 at 98,100 pounds (maximum structural limit landing weight) with required effective dry runway length of 5,150 feet and at 94,400 pounds with a required wet runway length of 5,150 feet. There is no definitive specification for a wet runway; however, Advisory Circular AC121-12 does provide certain guidelines for wet or slippery runways for certificate holders operating under FAR 121.

In the certification of airplanes such as the DC-9, the FAA requires, under FAR 25, demonstration of the horizontal distances necessary to land and come to a complete stop from a point 50 feet above the landing surface at each weight, altitude, and wind condition within the operational limits established by the applicant for the airplane. These tests establish the landing field length and speed performance data for the approved airplane flight manual required under FAR Part 121.195, "Landing Limitations: Destination Airports." This part states that the actual landing distance from 50 feet above runway threshold to touchdown, rollout, and stop, must be within 60 percent of the destination runway field length under dry runway conditions. The wet runway field length is an empirical value of 115 percent of the dry runway field length.

The airspeed for the above tests cannot be less than 1.3 times the stall speed (V_{S_O}) at the 50-foot point over the threshold, and no reverse thrust can be used during tests.

Applying the flight manual data for the wet runway conditions at Harry S Truman Airport, St. Thomas, the aircraft should have stopped (with 1.3 V_{SO} [123 KIAS] at 50 feet above the runway threshold) in 3,030 feet from the threshold of the runway, which allows for a 1,000-foot touchdown point and 2,030 feet stopping distance. However, the recorded airspeed showed a higher indicated airspeed than 1.3 V_{SO} at the 50-foot point. Adjusting the landing field length data on the chart for the higher airspeed (1.3 V_{SO} + 10 knots), the landing field length required would have been 5,615 feet and 60 percent of this, or stopping distance would have been 3,369 feet. Considering that the 3,369 feet includes the distances from 50 feet above the runway to touchdown, then the actual rollout on the ground would have been 3,369 feet minus about 1,000 feet, or a total ground stopping distance of 2,369 feet.

1.11 Flight Recorders

a. Cockpit Voice Recorder (CVR)

N938PR was equipped with a Collins Radio Model 642-C-1 cockpit voice recorder which was recovered without damage and had been operating satisfactorily. A CVR transcript was prepared which encompasses the cockpit conversation and radio communications during the approach and landing rollout. A Spanish-to-English translation of the transcript was also necessary, since the greater portion of the intracockpit communications was in Spanish.

The transcript reflected considerable crew discussion about the rain showers just west of the airport, and comments were also made about a large waterspout to the west of the island.

The copilot was flying the aircraft and the captain was calling out airspeeds and rates of descent during the approach. The windshield wipers were turned on during the approach. The tower transmitted the wind as "one two zero degrees at five knots" when the flight was less than a mile from touchdown. The sound of touchdown was normal, and the captain told the copilot to apply reverse thrust. The sound of reverse thrust was heard coming on and, shortly after, the copilot stated that the aircraft was not stopping. The captain told him to continue applying reverse thrust power, and an audible increase in reversing sounds was heard. About 21 seconds after touchdown, the copilot made a statement to the effect that they would not be able to stop on the runway, which was subsequently followed by impact noises. When the aircraft came to rest, sounds of the captain giving evacuation instructions were heard and ceased abruptly as power was shut off to the recorder.

b. Flight Recorder

N938PR was equipped with a Fairchild flight data recorder magazine, Model 5242, S/N 1916, which impresses on metal foil information concerning pressure altitude, indicated airspeed, magnetic heading, and vertical accelerations. It was recovered from the aft fuselage section of the aircraft, without evidence of damage, on the day following the accident.

Preliminary examination of the recorded data revealed that the altitude and indicated airspeed information did not correspond to the altitudes and speeds of the aircraft. In order to be able to utilize the information on the flight recorder tape from N938PR, it was necessary that a new calibration tape be made using known input values from electronic test equipment.

With the implementation of the refined calibration data, reduction of information from the recorder's tape indicated that the touchdown speed was 135 KIAS, and that the heading was 090° magnetic. At the end of about 25 seconds of travel after touchdown, the aircraft encountered a raised concrete sidewalk located approximately 5,282 feet from the landing end of Runway 9. At this time, the indicated airspeed was 57 knots, which was accompanied by an abrupt 15° heading change to the right. During the last 3.5 seconds of travel, the aircraft continued for about 200 feet down a paved street, where it finally came to rest after penetrating a metal building, on a heading of 060°.

1.12 <u>Wreckage</u>

The aircraft was intact. Fuselage damage was limited primarily to damage to the nose section, aft to about Station 218. The collapsing of the nose gear caused some structural damage to the electrical/electronic compartments. Both left and right leading-edge wing devices were damaged, the right wingtip was torn off, and the right wing rear spar was bent aft slightly at the tip. Both right and left wing flap damage was light.

The nose gear collapsed aft, breaking drag and door links. Both nose gear tires were damaged and the wheels separated from the axle at the wheel hubs. The right main gear No. 3 tire had deep cuts and was deflated. Other tires, Nos. 1, 2, and 4, were intact but varied in pressure as a result of tire damage. Skid patches were on the Nos. 1 and 2 tires and were oriented at an angle of 10° to 15° aircraft nose-left. No evidence of rubber reversion was found. Tire pressures were checked and recorded as follows: left nose gear 110 p.s.i., right nose gear deflated, left outboard main 90 p.s.i., left inboard main 130 p.s.i., right outboard main 88 p.s.i., and right inboard main--blown; tire pressure should have been 130 ± 5 p.s.i.

Both right and left brake accumulator pressures were normal. The right and left hydraulic reservoirs were normal. (Note: there was fluid loss from reservoirs when the flap actuator hydraulic fluid lines were removed to permit flap retraction in order to prevent further damage by ground equipment at the wreckage site.)

Examination of the last 1,400 feet of the runway revealed white tire streaks, typical of hydroplaning, which were relatable to N938PR. The light marks could not be traced back farther than 1,400 feet from the overrun end of the runway.

1.13 Fire

No fire occurred.

1.14 Survival Aspects

An orderly evacuation of the aircraft ensued after it came to rest, with all occupants except the first officer using the four over-the-wing emergency exits. The rear fuselage stair exit was operable but was not utilized in the evacuation.

1.15 Tests and Research

At the request of the Board, the aircraft manufacturer calculated the stopping distance required from the touchdown point for a DC-9-31 under the conditions 1/ and aircraft weight configuration that existed during the landing of Flight 340 at Harry S Truman Airport. Simulating a loss of effective braking (dynamic hydroplaning) and using a touchdown speed of 135 KIAS (taken from the flight recorder readout), the distance required to come to a full stop from the point of touchdown, using 2.0 EPR reverse with spoilers operative (no effective braking), was calculated to be 4,403 feet. FAA-certificated minimum runway length for the Caribair DC-9-31 aircraft under wet conditions, 91,920 pounds, full flaps, is 5,050 feet, which allows for a touchdown point of 1,000 feet down the runway.

Landing tests conducted by Eastern Airlines on a DC-9-31 type aircraft, using only 1.6 EPR reverse thrust and spoilers, showed deceleration rates from about 130 KIAS to 50 KIAS in 25 seconds, with observed ground roll distances of about 4,000 feet. These aircraft, however, were at a lighter weight than N938PR (91,920 lbs. versus approximately 80,000 lbs.)

National Aeronautics and Space Administration (NASA) Reports and FAA Advisory Circular No. 9-24 describe three known types of hydroplaning: dynamic hydroplaning, which occurs when there is standing water in the runway surface; viscous hydroplaning, which occurs when the runway is damp; and reverted rubber hydroplaning, which occurs where the rubber of a tire takes the appearance of its original uncured state, and is sticky and tacky, because of heat generated by friction between the tire footprint and a wet runway surface. It is interesting to note that once hydroplaning commences, it may persist down to speeds below the level where hydroplaning may normally be expected to start.

At the request of the Safety Board, NASA conducted runway slipperiness tests at Harry S Truman Airport using its diagonally-braked, instrumented automotive test vehicle 2/. Results of this test disclosed an average wet

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1/ Airport elevation sea level, temperature 78°F., runway gradient zero, wind calm, gross weight 91,920 pounds.

2/ Walter B. Horne, NASA, Langley Research Center, Hampton, Virginia, and Howard C. Sparks, USAF, Wright-Patterson Air Force Base, Ohio -- New Methods for Rating, Predicting, and Alleviating the Slipperiness of Airport Runways -- Society of Automotive Engineers Paper No. 700265, April 1970.

(.02 to .03 inches of water) to dry stopping distance ratio of 1.69:1. Applying these figures to the accident aircraft, we determine that the aircraft should have stopped in approximately 4,860 feet from the threshold for a wet runway. Applying figures from previous tests 3/ conducted by NASA showing a wet-to-dry stopping ratio of 2.21:1 for a flooded runway, it would have taken 5,860 feet from the threshold to stop.

A ground check of the spoilers, using the hydraulic hand pump in the wheel well, verified normal spoiler operation and that the spoiler system was capable of normal operation by manual actuation of the speed brake handle. An electrical bench check of spoiler actuator, wheel spin-up generators, and ground control relays did not detect any malfunction that would have prevented automatic spoiler operation.

Using accumulator pressure, no power on, operation of brake pedals verified normal braking capability for all four wheel brake systems. There was no evidence of hydraulic fluid leakage in the braking system. Brake wear indicators and tire tread depths were within minimum prescribed limits.

Electrical continuity and resistance checks of the spoiler and antiskid electrical circuits disclosed no broken wires or miswiring that would affect their operation. Functional testing of the spoiler, brake, and antiskid components under static and vibration conditions revealed no malfunction or discrepancies that would prevent normal or antiskid braking.

Pitot/static systems were checked for leakage and water contamination with no discrepancies noted. The captain's and copilot's airspeed indicators were removed, bench-tested, and found to be within specifications.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

N938PR had been maintained in an airworthy condition and there was no malfunction of any of the aircraft's structure, systems, or components that contributed to the accident.

The crew was certificated and qualified in accordance with existing company and Federal Aviation Regulations.

The crew of Flight 340 was provided with initial information of a wet runway and shower activity by St. Thomas Approach Control when the flight was cleared for an approach. At 1401, the flight advised Approach Control that it would hold southeast of the field to wait for the rain showers to clear. Touchdown occurred at about 1409, but there were no discernible tire marks on the runway that could be related to the touchdown point of N938PR. The reduction of flight information from the flight recorder

3/ Pavement Grooving and Traction Studies - NASA SP-5073 - Conference Report - November 18-19, 1968.

indicated that touchdown speed was 135 KIAS. Following touchdown, the spoilers were extended, wheel braking begun, and reverse thrust was initiated. However, a lack of decelerating forces was noted by the crew, several passengers, and witnesses. Heavy spray was thrown up by the aircraft as it progressed down the runway. Full reverse thrust, which was reported by the captain as 2.0 EPR, was applied by the copilot with the captain's assistance. Additional pressure on the brakes by the copilot, with assistance by the captain, failed to slow the aircraft significantly as it continued along the runway. The crew continued application of maximum available reverse thrust and pressure on the brake pedals until the aircraft came to rest.

The flight recorder trace showed large aberrations of airspeed commencing at about 90 KIAS during the deceleration. The flight recorder factual report and data graph reflects a mean fairing of these airspeed aberrations, placing the airspeed on contact with the raised sidewalk at 80 KIAS. The Board, in its further analysis of these aberrations, believes that they were the result of positive overpressures from the reverse thrust of the engines on the flight recorder pitot tube mounted on the vertical fin, and thus a curve through the minimum values of these aberrations would reflect more accurately the values of airspeed in this regime. This curve placed the impact with the raised sidewalk at about 57 KIAS. It should be noted that the airspeed values depicted by the flight recorder, below 100 KIAS, are generally not calibrated and, because of the nonlinearity of the sensor in this speed regime, must be considered less accurate than those above 100 KIAS.

Time-distance calculations, using incremental numerical integration (Trapezoidal Rule) from 135 KIAS (touchdown) for a 25-second interval to 57 KIAS (sidewalk impact) using a 4.3-knot headwind component, showed a groundroll of 4,392 feet to impact with the sidewalk. Using a distance of 5,383 feet from the threshold of Runway 9 to the sidewalk, this places the initial touchdown point at about 991 feet from the threshold of the runway.

The FAA-approved aircraft performance chart indicates that on a wet runway, gross weight 91,920 pounds, touchdown speed 124 KIAS, and zero wind, the minimum required runway length for landing is 5,050 feet. This is predicated on a touchdown point of approximately 1,000 feet from the approach end of the runway.

Witnesses' statements varied considerably as to the touchdown point -- placing it somewhere between 1,000 and 1,800 feet down the runway. The FAA tower controller, from his vantage point in the tower, stated that he observed the aircraft touch down about 1,800 feet down the runway. Passengers and ground witnesses also stated that the aircraft bounced after initial touchdown, which the Board believes could have consumed approximately 200 to 300 feet more of the runway before positive deceleration measures could have been accomplished by the crew.

The touchdown speed of 135 KIAS, depicted by the flight recorder, becomes significant with respect to the aircraft's stopping distance, since kinetic energy increases as a function of the airspeed squared, the 11 knots speed difference between reference speed and touchdown speed would have the equivalent effect of an increase in total gross weight of approximately 16,000 lbs. Under normal stopping conditions on a wet runway (without the use of reversing), a weight increase of that magnitude would require an additional runway distance of approximately 600 feet.

The Board believes that the following sequence best describes the events that occurred during the landing of N938PR.

The aircraft touched down at 135 KIAS (approximately 11 knots above specified) at a point approximately 1,000 feet from the approach end of the runway. Dynamic hydroplaning commenced almost immediately, with deceleration of the aircraft being effected only by reverse thrust until a point 1,400 feet from the overrun end of the runway was reached at a speed of 107 KIAS. At this point, the white tire streaks relatable to the tires of N938PR became visible, most probably indicating a change from dynamic hydroplaning to a viscous type hydroplaning as the aircraft tires broke through the deep water film. The aircraft proceeded on from this point, still at a very low coefficient of braking, decelerating to 57 KIAS as it passed through the airport boundary chain-link fence, and impacting the raised sidewalk. The aircraft continued for about 200 feet down a paved street where it finally came to rest, after penetrating a metal building, on a heading of 060°.

The Board was unable to determine exactly how much water was standing on the runway; however, it was estimated that the water depth was well in excess of the amount necessary (1/10 of an inch) for the initiation of dynamic hydroplaning. The existence of considerable water on the runway was further supported by witnesses who observed the heavy spray thrown up by a small aircraft landing just prior to N938PR, and by the airport fire chief who observed water estimated to be one-half of an inch deep on the runway, draining in the direction of the transverse runway slope. Since the runway does have a 1-percent transverse drainage gradient (which meets the FAA minimum in this regard), the presence of excess water can only be attributed to local terrain features. Indeed, the area north of the runway had been used as a catchment area for fresh water, substantiating the premise that the runway is particularly susceptible to relatively large amounts of water during periods of rain. Accordingly, the Board concludes that this aspect of the airport design and environment was also causally related to this accident.

The NASA tests, as discussed in the factual portion of this report (see Section 1.15, Tests and Research), essentially confirmed that considerable water must have been present on the runway during the accident landing, since the measured wet/dry stopping distance ratio of 1.69:1 indicates the aircraft could have stopped within the available runway even at the higher-than-normal touchdown speed. However, with a wet-to-flooded condition (water in excess of .2 of an inch), a stopping distance of 2.21 times the dry distance would have been required, which would have exceeded the available runway length.

2.2 Conclusions

Findings

1. The crew was qualified and certificated in accordance with existing company and FAA regulations.

2. The aircraft was properly certificated and was in an airworthy condition for the subject flight. Dispatch was found to be in accordance with proper procedures and the destination landing weight was well under maximum allowable for a wet runway condition.

3. Upon arriving in the vicinity of the Harry S Truman Airport, the flight delayed its landing for a few minutes until the rain shower was clear of the approach end of the runway.

4. Witnesses, including FAA tower personnel, stated that rain showers had been occurring intermittently since early in the morning. The Weather Bureau recorded 2.74 inches of rainfall during the 24-hour period.

5. Rain was encountered by the flight on final approach, and windshield wiper operation was clearly audible on the cockpit voice recorder.

6. Ground witnesses observing a light twin-engine aircraft landing shortly before Flight 340 noted a heavy spray of water which almost engulfed the aircraft. These same witnesses also observed heavy water spray as the DC-9 landed.

7. The fire chief estimated that there was approximately one-half of an inch of water on the runway as he proceeded to the accident site.

8. There is no crown on Runway 9-27, but it has a 1-percent transverse gradient, south to north.

9. The flight reçorder data indicates that the aircraft touched down at a speed 11 knots faster than the specific reference speed, which was 124 KIAS.

10. The FAA certificated Caribair to operate DC-9-31 aircraft on Runway 9, which has an effective length and width of 5,150 feet by 100 feet. The minimum FAR wet runway required for Flight 340 at 91,920 pounds gross weight was 5,050 feet. The computed stopping distance for a DC-9-31 in the same configuration as Flight 340 on a wet runway, with a touchdown speed of 124 KIAS, is 3,030 feet from the approach end of the runway.

11. The manufacturer's computer calculations for a DC-9-31 aircraft in the same configuration as Flight 340 for a condition where the runway braking coefficient is near zero (dynamic hydroplaning) show a stopping distance of 4,403 feet after touchdown, using maximum reverse thrust (2.0 EPR) and spoilers only at the higher touchdown speed of 135 KIAS. The same calculations, using a touchdown speed of 124 KIAS, show a stopping distance of 3,998 feet after touchdown. It should be noted, however, that these calculations do not take into consideration any loss of reverse thrust at the slower speeds resulting from reinjestion of the exhaust gases into the engines.

12. At the landing weight and speed of the aircraft at touchdown with the existing runway conditions, the Board believes that more than the remaining useable runway length was necessary to stop the aircraft.

13. Correlation of the flight recorder and voice recorder shows that the aircraft had decelerated to 57 KIAS at a point 132 feet off the end of the runway, where the aircraft hit a fence and street curb.

14. No rubber reversion was found on any of the tires; however, there was a skid patch found on each of the left main landing gear tires at an angle of 10°, -15° off centerline, indicating a yaw to the left when this occurred.

15. Examination of the last 1,400 feet of the runway revealed white tire streaks, relatable to N938PR, which were of the type frequently exhibited in known cases of hydroplaning.

16. The passengers and crew evacuated from the aircraft without major difficulties.

Probable Cause

The Board determines that the probable cause of this accident was the loss of effective braking action caused by dynamic hydroplaning of the landing gear wheels on a wet/flooded runway. Contributing factors were a higher-than-normal touchdown speed and the location of the airport and its topography which permitted excess levels of water to accumulate on the runway.

3. RECOMMENDATIONS AND CORRECTIVE ACTIONS

The Board considers that the landing limitations, as specified in Section 121.195 of the Federal Aviation Regulations for dry runways, are adequate. This requirement states essentially that the actual landing distance, from a point 50 feet above the runway threshold to rollout and full stop, must be within 60 percent of the available runway.

However, it is the Board's opinion that the empirical extra 15 percent of runway presently allowed for a wet runway condition is not adequate for all wet or slippery runways since, in many instances, the wheel brakes are completely ineffective. It is interesting to note that for conditions attendant to this accident, according to the manufacturer's data, the aircraft could have been brought to a complete stop in 4,437 feet of runway using only spoilers and maximum continuous reverse thrust from a normal touchdown speed of 124 KIAS (i.e., without brakes). Thus, allowing for a 1,000-foot touchdown point and considering criteria based only on spoilers and reverse thrust, the wet runway requirement in this case would have been, theoretically, 122 percent of the FAR-required dry runway length (4,400 feet) or approximately 5,400 feet. In this case, therefore, the application of a weight limitation would have been necessary to conform with the 5,150 feet of runway available, if spoilers and reverse thrust were the only decelerative systems available.

In light of the above, the Board also examined stopping data for Boeing 727-100 aircraft using reverse thrust only. Applying the above principle, this data would give wet runway criteria factors for B-727-100 aircraft of 117 percent of the FAR-required dry landing field lengths at a landing weight of 100,000 pounds, ranging up to 130 percent at 135,000 pounds maximum landing weight.

It is clear to the Board that more attention to the wet or slippery runway problem is needed by the entire aviation community to cope with this problem adequately. The Board is cognizant of actions now being taken to minimize this problem, particularly in the areas of runway grooving, measurement of actual runway braking coefficients, and enforcement of the operators' responsibility to restrict operations into known hazardous runway conditions. However, the Board is concerned, since the problem becomes magnified with the advent of the high landing energy wide-body jets and consequent larger number of passengers exposed to this hazard.

In view of the foregoing, the Safety Board believes that the present criteria in Part 121 for determination of wet runway landing distances needs reevaluation. One possible method of determination might be based on stopping distances by the use of reverse thrust without credit for wheel braking. Another method was proposed by Messrs. Walter B. Horne of NASA and Howard C. Sparks, USAF, which was presented at the National Air Transportation Meeting in New York on April 20-23, 1970, and published in SAE paper 700265 which involves new techniques for the measurement of runway slipperiness by utilizing a diagonally braked automobile.

In regard to the latter, the Board has forwarded a letter to the Administrator recommending that the FAA evaluate this proposed NASA method for the measurement of runway slipperiness and compare results to the present FAR wet runway length requirements and consider the feasibility of incorporating the NASA traction test procedures in revised wet runway length requirements for air carrier operations. (See attachments for copy of Chairman's letter to the Administrator and the Administrator's reply.)

As an immediate corrective measure, the Virgin Islands Airport Authority has had the runway grooved, which has reduced the wet-to-dry runway stopping distances, for the major portion of the runway, to near unity (1.18:1) and for the portions of the runway where tire rubber is impregnated from a value of 2.17:1 to 1.71:1. The Board believes that the runway grooving program should be expedited and, when incorporated by the nation's air carrier airports, it should substantially reduce the overrun or off-runway type of hydroplaning/slippery runway accidents. As a possible look in the future, the Board believes that, under ice and snow conditions, it might be quite feasible to use an airport-owned diagonally-braked test vehicle to give actual day-by-day braking conditions for airport runways which could be relayed to incoming flights and/or dispatchers.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

September 16, 1970

RECOMMENDATIONS AND CORRECTIVE ACTION

On September 25, 1970, the Board sent the following letter to the Administrator of the Federal Aviation Administration:

"The National Transportation Safety Board is now investigating the JT9D-3 engine failure and in-flight fire involving American Airlines, Boeing 747, N743PA, which occurred during takeoff from the San Francisco International Airport on September 18, 1970. A failure occurred in the No. 1 engine 13 seconds after lift-off, followed by a fire warning. The flight returned to the airport after shutdown of the engine and extinguishing of the engine fire.

"During the return to the airport, the flightcrew experienced difficulty in extending the landing gear and the wing flaps after parts of the failed engine severed the hydraulic and pneumatic systems' supply lines. The captain elected to "go around" and extended the landing gear by the alternate system. The aircraft made a successful landing, and there were no injuries to the 15 crewmembers or the 127 passengers.

"Our preliminary investigation of the engine failure revealed that a separation occurred to the rim portion of the second-stage turbine disk. It has been confirmed that failures of at least four of seven first-stage turbine blades contributed to the fracture of numerous second-stage turbine vane feet. As a result of the cumulative effect of the broken vane feet, an aft deflection of the nozzle support resulted, causing interference with and rubbing of the second-stage turbine disk. Progressive weakening of the disk rim area resulted in the in-flight failure of the rim. We have also confirmed that although failure mode of this second-stage turbine disk rim was similar to that of the Air France JT9D-3A engine failure of August 17, 1970, the failure mechanism was entirely different.

"As a result of our investigation and meeting with Pratt & Whitney engineering staff personnel and your Eastern Region Flight Standards personnel, immediate inspection action was initiated. This was considered fully responsive to the immediate needs of this situation. The Safety Board commends the Administrator's formalizing this corrective action in the form of your engineering alerts of September 19 and 23, 1970.

"In view of the potentially catastrophic results of the failure such as experienced by American Airlines, the Board remains concerned about this matter in the longer range sense and would urge the Administrator to initiate further expeditious actions in order to preclude recurrence of similar failures. Accordingly, the Board offers the following observations.

"It is generally recognized that the JT9D engine is normally operating near critical turbine temperature conditions. This is particularly true when operating in high ambient temperatures. Several JT9D engines have recently been removed from service and returned to Pratt & Whitney for overhaul, because of failed first-stage turbine blades as well as broken second-stage vane feet. There is evidence that these failures had occurred as the result of operation at higher-than-desirable temperatures.

"In the case of the most recent American Airlines turbine disk rim separation, there was evidence that at least six first-stage turbine blades had sustained varying degrees of fractures some time prior to the final failure. Our technical staff finds it most difficult to reconcile the fact that the airborne vibration monitoring equipment installed in the aircraft was either inadequate or was not effectively utilized in detecting this condition. We also feel that other engine instrumentation, namely: fuel flow, engine pressure ratio, and exhaust gas temperature should have been capable of collectively reflecting appropriate changes in the engine's operating parameters, if such instrumentation were properly calibrated and the respective readings were recorded and closely analyzed.

"In this area, we recommend the following be considered.

1. Initiate appropriate action toward the operators' maintaining a program of current engine condition monitoring.

2. Review engine instrumentation calibration and existing instrument tolerances to assure the most precise engine operating parameter indications.

"Further, it appears that the reliability of the Boeing 747 auxiliary power units is somewhat marginal. When engine starts must be accomplished by the use of ground units, pneumatic duct pressures may often be less than what is required, even when multiple units are used. The result is usually a start that may involve a temperature rise, approaching the "recoverable stall" condition. Since exhaust gas temperature, although above normal under these conditions often do not exceed the published limits, no record is made of these occurrences, and there is no possible way to determine how many times an engine hot section has been exposed to higher-than-normal temperatures. The effects of thermal transients are known to be cumulative and conceivably affect turbine blade reliability.

1. Investigation

The National Transportation Safety Board received notification of the accident about 1100 G.m.t., on August 13, 1969. Working groups were established by the Investigator-in-Charge for Operations/Witnesses, Structures/Systems, and Flight/Voice recorders. Parties to the investigation were Caribbean Atlantic Airlines, Inc., the Federal Aviation Administration, and Douglas Aircraft Company.

The on-scene phase of the accident investigation lasted approximately 4 days.

2. Hearing

No hearing was held on this accident.

3. Preliminary Reports

A preliminary factual report on the accident was released for public information on October 24, 1969.

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Crew Information

Captain Victor F. Arocho, aged 45, was employed by Caribair on December 6, 1956, and as captain-in-command of Flight 340, was occupying the left seat. He was upgraded to captain on September 27, 1968. He held Airline Transport Pilot Certificate No. 44339, with type ratings on the Convair 240/340/400/600/640, DC-3 and DC-9, and commercial privileges in single-engine and multiengine land aircraft. He satisfactorily passed his last examination for a Federal Aviation Administration (FAA) first-class medical certificate on July 31, 1969, with the limitation that he must wear corrective glasses for near vision.

According to Caribair records, he had accumulated a total of 9,529 flying hours. Pilot time in the Douglas DC-9-31 aircraft was 417:30 hours, of which 120 hours were acquired in the last 90 days prior to the accident. He had flown 4:12 hours in the last 24 hours prior to this accident.

On March 8, 1969, he satisfactorily passed a 6-month proficiency check in the Douglas DC-9 aircraft. Line checks in the DC-9 aircraft were satisfactorily accomplished on October 2, 1968, January 25, 1969, and May 6, 1969.

First Officer Gilberto A. Gonzalez, aged 29, was employed by Caribair on September 16, 1963, and held Commercial Pilot Certificate No. 1531084, with aircraft single-engine and multiengine land and instrument ratings. He also was an FAA-approved Douglas DC-9 ground instructor. He satisfactorily passed an FAA first-class medical examination on November 27, 1968, without limitations. According to Caribair records, he had accumulated a total of 3826:40 flying hours. Pilot time in the DC-9-31 was 881:40 hours, of which 124 hours were acquired in the last 90 days prior to the accident. He had flown 4:06 hours in the last 24 hours prior to this accident. Initial checkout in the DC-9 was accomplished on December 23, 1967, and his latest annual DC-9 check was satisfactorily accomplished on January 8, 1969.

Miss Evelina Marrero Soto, Miss Juana Crespo de Heuertas, and Mr. Pedro Zorilla were employed by Caribair on January 8, 1950, August 11, 1964, and December 17, 1968, respectively, and were serving as flight attendants aboard Flight 340. Their records showed satisfactory accomplishment of initial and recurrent DC-9 training.

On August 24, 1969, a post-accident flight check was given to both the captain and first officer by an FAA check airman. According to his statement, both pilots demonstrated satisfactorily that they were qualified and capable of performing their assigned duties in the DC-9-31 model aircraft.

At the time of the accident, the aircraft was configured to carry a maximum of 115 passengers and a crew of seven.

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Attachment 1

DEPARTMENT OF TRANSPORTATION
NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20591

OFFICE OF
THE CHAIRMAN

August 31, 1970

Honorable John H. Shaffer
Administrator
Federal Aviation Administration
Washington, D. C. 20590

Dear Mr. Shaffer:

The National Transportation Safety Board is continuing its investigation of the Caribair DC-9 overrun accident on August 12, 1969, at Charlotte Amalie, St. Thomas, Virgin Islands. The Board is increasingly concerned over the apparent increase in the number of wet runway overrun accidents. Another recent incident occurred when an Airlift International DC-8-63 went off the end of a 9,400-foot wet runway at Houston International Airport.

On May 14, 1970, the Board was briefed by a representative of the National Aeronautics and Space Administration (NASA) on their joint USAF/NASA Combat Traction Program and was highly impressed by the apparent correlation of wet-to-dry braking distances between the test vehicle and various aircraft. The tests showed differences in runway slipperiness under wet conditions and for a variety of different types of runways. Accordingly, the Safety Board requested NASA to conduct a runway slipperiness evaluation of Houston International Airport and Harry S Truman Airport in St. Thomas in order to correlate runway slipperiness as a possible causal factor in the aforementioned accident and incident. We were pleased that representatives of your Administration accepted our invitation to participate in both of these tests.

These tests did, indeed, show some very interesting results. The runway at Houston was the most slippery of all those previously tested, with an average wet-to-dry stopping distance ratio of 2.73:1. A DC-8-63 landing at the weight of the aircraft involved in the Houston incident would have needed a wet runway length, based on NASA test data, considerably greater than that required by the current Federal Aviation Regulations. The tests at St. Thomas also correlated very well with the known accident data. Since this runway has now been grooved, we were able to obtain a direct comparison between grooved and ungrooved runway stopping capabilities. The grooving of this runway has dropped the wet-to-dry stopping ratio (slipperiness ratio) to near unity (1.18:1) for a major portion of the runway.

In view of the above tests and other NASA test data, the Board recommends that the FAA:

1. Reevaluate the adequacy of the wet runway stopping distance requirements of the Federal Aviation Regulations, and

2. Consider the feasibility of incorporating the NASA traction test procedure in revised wet runway length requirements for air carrier and other appropriate aviation operations.

Complete data on these tests will be available from NASA shortly. A copy of the data will be provided your Flight Standards staff as soon as possible.

Sincerely yours,

John H. Reed

John H. Reed
Chairman

Attachment 2

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

18 SEP 1970

Honorable John H. Reed
Chairman, National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

Dear Mr. Chairman:

This is in reply to your letter of 31 August 1970, regarding wet runway overrun accidents.

The Federal Aviation Administration has been working with NASA, USAF, the air transport industry, and other agencies here and abroad to establish appropriate criteria and standards regarding wet runway traction and its application to aircraft stopping distances. Many approaches have been investigated. None of the vehicles tested produced data that could be correlated with aircraft stopping distance. Recently, NASA has been evaluating data obtained from a diagonally-braked vehicle which is showing excellent correlation with aircraft stopping distance. The FAA evaluated the use of a James Brake Decelerometer (JBD) to determine its application in computing aircraft stopping distances. Industry rejected a proposal to use the JBD system in a trial application due to the inability to correlate wet surface JBD stopping distances to aircraft stopping distances.

We have been closely associated with NASA and are intimately familiar with all of their test activities and results therefrom. In fact, our latest contact with NASA on this matter was 25 and 26 August 1970 when our Runway Texture Committee visited NASA and was briefed on the latest data available. This included results from the NASA/USAF Combat Traction project and the tests and analyses conducted in conjunction with the St. Thomas and Houston accidents.

We are actively working with NASA to conduct a series of tests on a jet transport aircraft with a dual-wheeled configuration main gear. Such data are required to fill a gap in the data that NASA has accumulated to date. In addition, we are closely following the work NASA is doing on wheel spin-up under hydroplaning conditions and correlation of rain rate with depth of water on a runway surface.

With regard to your recommendations, we propose to utilize the results of NASA tests with the diagonal-braked vehicle to:

1. Reevaluate Federal Aviation Regulations wet runway stopping distance requirements.

2. Establish the NASA traction test procedure, i.e., diagonal-braked vehicle, as an acceptable procedure for establishing runway characteristics under dry and wet conditions.

The runway texture aspects, i.e., grooving and porous surfaces as tested and reported by NASA, are being considered for application in forthcoming airport certification rules.

We will appreciate all of the information and assistance that your staff can provide us in this regard.

Sincerely,

G. S. Moore

G. S. Moore
Acting Administrator