CIAIAC

COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
E INCIDENTES DE
AVIACIÓN CIVIL

Report A-002/2007

Accident involving a De Havilland DHC8-300, registration PH-DMU, operated by Denim Air for Air Nostrum, at El Prat Airport (Barcelona), on 23 January 2007

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MINISTERIO DE FOMENTO

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Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the event and its causes and consequences.

In accordance with the provisions of Law 21/2003 and pursuant to Annex 13 of the International Civil Aviation Convention, the investigation is of exclusively a technical nature, and its objective is not the assignment of blame or liability. The investigation was carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

Table of contents

Abbreviations

00°	Degrees
00 °C	Degrees centigrade
AENA	Spain's airport and air navigation authority
AIP	Aeronautical Information Publication
APP	Approach control
ATA	Air Transport Association of America
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATPL(A)	Airline Transport Pilot License (Airplane)
ATZ	Aerodrome Traffic Zone
BCN	IATA designator for Barcelona airport
BKN	Broken clouds
cm	Centimeter(s)
CPL(A)	Commercial Pilot License (Airplane)
CTR	Control area
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DLU	Specific kind of computer sound file
DME	Distance-Measuring Equipment
FDR	Flight Data Recorder
FA	Flight Attendant
FL<number>	Flight level expressed in hundreds of feet
ft	Feet
GPWS	Ground Proximity Warning System
gr/cc	Grams per cubic centimeter
GS	Glide slope
h	Hour(s)
HP	Horsepower
hPa	Hectopascal(s)
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
ILS-CAT III	Category III Instrument Landing System
IR(A)	Instrument flight Rating (Airplane)
kg	Kilogram(s)
km	Kilometer(s)
kt	Knot(s)
LEBL	ICAO designator for Barcelona airport
LEPP	ICAO designator for Pamplona airport
LESO	ICAO designator for San Sebastián airport
LNG	Aircraft landing time
LOC	ILS Locator
LT	Local Time
m	Meter(s)
MAC	Mean Aerodynamic Chord
mb	Millibar(s)
MEL	Minimum Equipment List
METAR	Aviation routine weather report
MLG	Main Landing Gear
mm	Millimeter(s)
MTOW	Maximum Takeoff Weight
NDB	Non-Directional Beacon
NLG	Nose Landing Gear
NM	Nautical miles
NOTAM	Notice To Airman

Abbreviations

OVC	Overcast
P/N	Part Number
PAPI	Precision Approach Path Indicator
PH-DMU	Registration of accident aircraft
PNA	IATA designator for Pamplona airport
PPL(A)	Private Pilot License (Airplane)
PTU	Power Transfer Unit
QNH	Setting that will cause altimeter to read field elevation
RWY	Runway
s	Second(s)
S/N	Serial Number
SNOWNOTAM	Snow Notice To Airman
SPECI	Special aerodrome weather report
T/O	Time at which aircraft takes off
TWR	Aerodrome control tower
UTC	Coordinated Universal Time
VHF	Very High Frequency
VOR	VHF Omnidirectional Range
WAV	Generic type of computer sound file
WOW	Weight on Wheels

Synopsis

Owner and operator:	Denim Air
Aircraft:	De Havilland DHC8-300; Registration PH-DMU
Date and time of accident:	23 January 2007; at 12:50 (LT)
Site of accident:	Runway 25L at Barcelona airport
Persons onboard:	4 crewmembers and 19 passengers
Type of flight:	Commercial air transport – Scheduled passenger flight
Date of approval:	27 October 2010

Summary of accident

The aircraft was on a scheduled passenger flight and was preparing to land at Barcelona airport. On final approach the crew selected the gear down, but only the main landing gear extended. The nose gear remained retracted. The landing was aborted and the crew tried several times to lower the gear using the normal and then the emergency procedure, but was unable to lower the nose gear. The aircraft landed with the nose landing gear (NLG) up, both NLG doors open and the main landing gear (MLG) down and locked. The aircraft was evacuated on the runway. There were no injuries.

1. FACTUAL INFORMATION

1.1. History of the flight

On 23 January 2007, the aircraft, a DeHavilland DHC8-300, registration PH-DMU, was on a scheduled passenger flight, number IB-8401, departing from Pamplona airport (LEPP) en route to Barcelona airport (LEBL). It was operated by Denim Air for Air Nostrum and its ATC call sign was ANS-8401. Onboard were two pilots, two flight attendants and 19 passengers.

It was that crew's third flight of the day on the same aircraft. On the first flight, they had departed San Sebastian airport (LESO) at 07:47 (local time)[1] and landed at Barcelona airport at 08:46.

On the second flight, they took off from Barcelona airport at 09:48 and landed at Pamplona airport at 10:55. It had snowed at this airport shortly before landing. After a 32-minute stopover, they took off at 11:27 en route to Barcelona. They reached the vicinity of the airport at 12:30. Weather conditions at Barcelona airport were good, with visibility in excess of 10 km, scattered clouds and a temperature of around 10 °C.

As they were on final approach to runway 25R, with the copilot as the pilot flying and the airplane in the ILS localizer path, the crew moved the landing gear selector lever to lower the gear. They noted that the indicating lights for the main gear were green, while the lights for the nose gear were red. The crew reported feeling mechanical vibrations from the area of the nose gear. They cycled the gear once again, only to receive the same nose gear not down indication. At that moment the captain took control of the aircraft and aborted the landing.

The crew then remained in a holding pattern at 3,500 ft, during which time they repeated their efforts to lower the gear. They finally attempted the alternative gear extension procedure, without managing to obtain a down and locked indication for the front gear.

The captain eventually declared an emergency, reported the problem to Air Traffic Control and requested the assistance of emergency services on the runway. He then informed the flight attendants of the situation and of the possibility of having to do an emergency evacuation on the runway.

Some 20 minutes after the initial approach and after reviewing the applicable emergency procedures, the captain decided to land with the nose gear as it was at that time.

[1] All times in this report are local. To obtain UTC (Coordinated Universal Time), subtract one hour from local time.

Figure 1. Picture showing ice in front gear wheel well

The landing took place at around 12:50 on runway 25L. The crew kept the nose of the airplane off the ground as long as possible before lowering it, after which they continued moving just over 200 m with the nose resting on the asphalt before coming to a stop on the runway between taxiways G-4 and G-5. No fires were reported during the landing.

Emergency services were ready at the foot of the runway as the aircraft made the landing. The aircraft was emergency evacuated without incident or injury to passengers or crew.

As reported by the crew, the evacuation of the nineteen passengers proceeded in relative order, given the haste typical in this kind of situation.

Approximately half an hour after the airplane was evacuated, the front part of the aircraft was lifted with a crane so as to remove the airplane from the runway. Once the airplane's nose was lifted, the alternate extension mechanism for the nose landing gear was activated in the cockpit, after which the gear lowered and locked correctly. During this operation, several 10-cm long pieces of ice fell to the runway from the nose landing gear wheel well. There was also a layer of ice over 5 cm thick on the nose landing gear wheel well doors and on the nose landing gear leg.

As part of the post-accident inspection, the airplane was placed on jacks and the nose gear was cycled twice, with the nose gear lowering and locking correctly.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal				
Serious				
Minor				Not applicable
None	4	19	23	Not applicable
TOTAL	**4**	**19**	**23**	

1.3. Damage to aircraft

There was minor damage to the aircraft. During the last 213 m traveled on the runway, the two nose gear wheel well doors were grinding against the asphalt and detached. No additional damage was observed.

1.4. Other damage

There was also no external damage. The nose wheel well doors, however, did leave a mark on the runway resulting from the contact they made with the asphalt.

1.5. Personnel information

The crew consisted of the captain, the copilot and two flight attendants.

1.5.1. *Pilot in command*

The captain was 32 years old and a Dutch national. He had received his airline transport pilot license ATPL(A) in 2002 and was rated on the DHC8 and Fokker 50. He had been a captain for four years and had a total flying experience of 5,000 h, of which 1,800 h were on the type. Both his license and corresponding medical certificate were valid. His last proficiency check had been on 23 October 2006.

1.5.2. *Copilot*

The copilot was 30 years old and a Spanish national. He had been issued a private pilot license PPL(A) in 2000 and his commercial pilot license CPL(A) in 2002. He obtained his multi-engine piston land rating in 2006 and had been instrument IR(A) and DHC8 rated since 2007.

He had a total flying experience of 500 h, of which 35 h had been on the type. Both the license and corresponding medical certificate were valid. His last proficiency check had been on 15 September 2006.

1.5.3. *Flight attendants*

The cabin crew consisted of two flight attendants who had both valid flight and medical certificates. Their training is summarized in the following table:

Flight attendant No. 1		Flight attendant No. 2	
Course	Date	Course	Date
Initial training	04-07-2005	Initial training	25-10-2006
DASH conversion training	09-07-2005	DASH conversion training	28-10-2006
CRJ conversion training	14-07-2005	DASH conversion training	30-10-2006
1 FA training	14-07-2005	CRJ conversion training	02-11-2006
DASH conversion training	05-05-2006	Annual recurrent training	03-11-2006
DASH recurrent training	13-06-2006		
Annual recurrent training + MMPP	15-06-2006		
CRJ recurrent training	27-07-2006		
Purser's course	31-08-2006		
DASH recurrent training	10-05-2007		
CRJ conversion training	24-05-2007		
CRJ 900 differences training	28-05-2007		
Annual recurrent training	22-06-2007		

1.5.4. *Information regarding flight crew's activity on day of accident*

The total activity time for the crew on the day of the accident was 4:06 h. The following table shows a summary of the specific flying times for that day's flights.

Flights	Flying time				
	Chocks	Takeoff	Landing	Chocks	Total
ANS-8851 San Sebastián-Barcelona	07:44	07:47	08:46	08:48	1:04
ANS-8400 Barcelona-Pamplona	09:31	09:48	10:55	10:56	1:25
ANS-8401 Pamplona-Barcelona	11:26	11:27	12:50	—	1:24

1.6. Aircraft information

1.6.1. *General*

The DeHavilland Canada DHC-8-315 DASH 8 is a high-wing aircraft designed for short-range commuter flights. It received its type certificate in 1985. The accident aircraft,

registration PH-DMU, was manufactured in 2001 with serial number 568. Its maximum takeoff weight (MTOW) was 19,495 kg and it could carry 52 passengers. It was equipped with two PRATT & WHITNEY (Canada) turboprop engines, model PW123E, generating a power of 2,380 HP.

1.6.2. *Weight and balance*

The weight and balance sheet prepared at Pamplona airport for aircraft dispatch listed the following weights:

• Total payload:	1,600 kg		
• Operating empty weight:	12,968 kg		
• Actual zero fuel weight:	14,568 kg	Maximum	17,917 kg
• Takeoff fuel:	1,650 kg		
• Actual takeoff weight:	16,218 kg	Maximum	19,495 kg
• Fuel added by the crew:	600 kg		
• Actual landing weight:	15,618 kg	Maximum	19,051 kg

In order to execute the airplane balancing procedure, the passenger cabin is divided into two sections. Section OA includes seat rows 1 to 7 and section OB rows 8 to 15. Of the first eighteen people to board the airplane, four were seated in section AO and fourteen in section OB. The nineteenth passenger, who boarded at the last minute, did not have a seat assigned, and thus was not included in the calculation.

The change in index units when transferring 1 kg of weight from cabin section OA to section OB is 0.0211 units per kg. The effect of transferring five passengers located in section OA to section OB is estimated at seven units.

The balance calculation was performed according to these equivalencies, which yielded that the center of gravity had a balance index of 112 units, within prescribed limits, which are 29.10% MAC (index of 105.13 units) and 40% MAC (index of 119 units).

1.6.3. *Landing gear information*

This type of airplane has a retractable tricycle gear with two identical wheels on each leg. The main landing gear retract aft and up into the aft engine nacelle area. The nose wheel leg folds forward and upward and is housed in the nose wheel well. The two nose leg wheels have 22 × 6.50 - 10 tires[2]. The wheel diameter is 55.8 cm. The nose wheel well is at a height of 75 cm from the ground.

[2] These measures correspond to the maximum diameter and the width and diameter of the hub all expressed in inches.

When the nose landing gear is down, the opening is closed by the two front doors, which only open for as long as it takes the wheels to lower. There are also two aft doors that are dragged by the motion of the nose leg and which rotate down and out to open and remain open while the gear is down (See Figure 2). The nose leg can be steered by means of a wheel (tiller) located on the captain's side.

The airplane has two independent hydraulic systems, each of them powered by one of the two engines. Specifically, the landing gear is operated by the (right) the No. 2 hydraulic system, which is powered from No. 2 engine driven hydraulic pump.

In the cockpit panel there are three lights arranged in three rows and three columns, used to indicate the position of the landing gear when the lever is actuated. If the lights are amber, that means the front doors are open (gear in transit). If they are green, the gear is down and locked. If they are red, the gear is not locked (both when deployed or retracted).

The lever used to operate the gear is also lit. If it turns amber while the other lights are red, this indicates that the gear is in transit. If it remains lit after retraction, this indicates that the door sequence has failed.

Once this light turns on, the gear may only be lowered using the alternate release.

In the event of a No. 2 hydraulic system failure, the power transfer unit (PTU) automatically transfers power from the No. 1 system to the No. 2.

Figure 2. Nose gear

Figure 3. Gear lever and lights

The alternate procedure for lowering the gear (manual mode) is performed as follows:

Figure 4. Gear inhibit switch

1. Select the landing gear inhibit switch to "inhibit", the switch is located in the copilot's overhead panel under the door that covers the main landing gear release handle. Actuating this switch releases all hydraulic pressure from the landing gear system.
2. Place the gear release handle in the "Down" position so as to keep hydraulic pressure from interfering with the manual release of the gear during the performance of the emergency checklist.
3. Open the door that covers the main gear release handle and pull said handle down to lower the main gear (see Figure 5).
4. Open the panel on the floor to the left of the copilot and pull up on the lever. This will tension a cable and release the front gear. Alongside this lever there is a compartment into which a bar can be inserted and moved back and forth along the airplane's longitudinal axis to manually operate an emergency pump, the purpose of which is to aid in extending the main gear.

The nose gear leg rotates down and back on two pivots to lower. The gear down position is confirmed by a drag strut that locks into place when straightened. In transit, the strut hinges to allow the wheels to lower and raise. In the gear up position, the drag strut returns to its straightened position, now horizontal, and locks (see Figure 7). If the gear is lowered using the alternate system, the front doors remain open during the landing.

Figure 5. Main gear manual lever

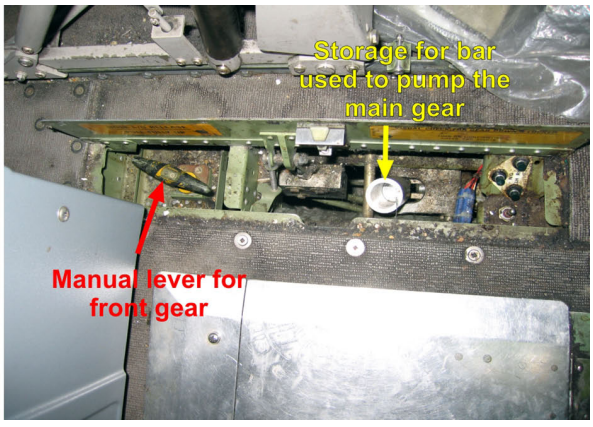

Figure 6. Manual front gear lever

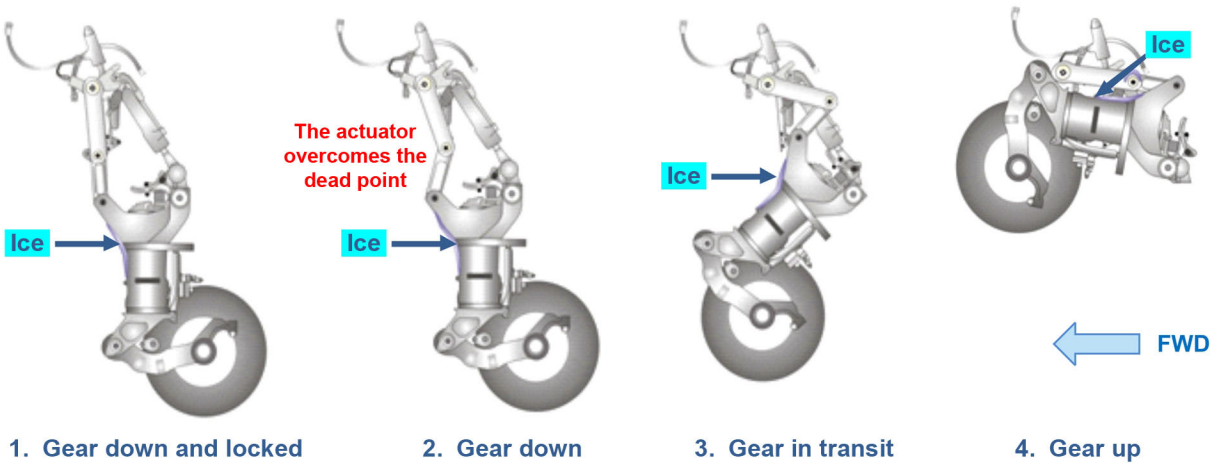

Figure 7. Sequence for retracting front gear

There is a ground proximity warning system that alerts the crew with voice alerts and visual indications when the gear is up and there is inadequate separation with the ground during the cruise and approach phases. More specifically, if the airplane is at an airspeed of below 178 kt and the altitude recorded by the altimeter is 500 ft with the gear up or not locked, a "TOO LOW - GEAR" voice alert will sound. This warning is linked to the air/ground sensors so as to inhibit the warning for a certain period of time, controlled by a timer, during takeoff operations. This is so that the alarm is not sounded after the gear is raised and the weight on wheels signal is removed.

1.6.4. *Aircraft maintenance information*

During the investigation it was revealed that there were no maintenance issues involving the landing gear (ATA 32) or the hydraulic system (ATA 29) in the year prior to the accident.

There was no evidence in the maintenance documentation that any minimum equipment list (MEL) items had been deferred in over a month, and the non-MEL deferrals were from a week before.

1.6.5. *Airplane landing performance*

In keeping with the indications in the flight manual, with a weight of 15,500 kg, the aircraft would need approximately 550 m to land with the flaps deployed 15° to 35° at standard temperature and pressure conditions. A head or tail wind would vary the length of runway needed, as would the conditions under which the normal landing takes place.

For the weight specified above, the landing reference speed ranges from 91 kt to 98 kt, depending on flap position.

The Flight Manual also sets an aircraft landing limitation of at most 15 mm of slush on the ground.

1.7. Meteorological information

1.7.1. *Meteorological conditions in Pamplona*

The METAR SPECI information for Pamplona airport at 10:00 UTC and 10:30 UTC on 23 January 2007 was as follows:

SA 23-01-2007 10:00 METAR COR LEPP 231000Z 31004KT 270V340 8000 SCT012 BKN130 01/00 Q1010 RESN=

SP 23-01-2007 10:00 SPECI LEPP 231000Z 31004KT 270V340 8000 SCT012 BKN130 01/00 Q1010 RESN=

SA 23-01-2007 10:30 METAR LEPP 231030Z 00000KT 9999 SCT015 BKN190 02/01 Q1010 RESN=

This means that the prevailing weather conditions were:

10:00 Winds predominantly from 310°, varying between 270° and 340°, at 4 kt. Visibility of 8 km. Scattered clouds at 1,200 ft and broken at 13,000 ft. Outside temperature of 1 °C and dew point at 0 °C. QNH 1,010 HPa (mb). Recent snow.

Special report giving the same forecast.

10:30 Winds calm, visibility in excess of 10 km. Scattered clouds at 1,500 ft and broken at 19,000 ft. Outside temperature of 2 °C and dew point at 1 °C. QNH 1,010 HPa (mb). Recent snow.

1.7.2. *Meteorological conditions in Barcelona*

The METAR information for Barcelona airport at 11:30 UTC on 23 January 2007 was as follows:

SA 23-01-2007 11:30 METAR LEBL 231130Z 28009KT 230V330 9999 FEW023 SCT220 10/M01 Q1004 NOSIG=

This means that weather conditions at 11:30 were:

11:30 Winds predominantly from 280°, varying from 230° to 330°, at 9 kt. Visibility in excess of 10 km. Few clouds at 2,300 ft and scattered clouds at 22,000 ft. Outside temperature of 10 °C and dew point of 1 °C. QNH 1,004 HPa (mb).

1.8. Aids to navigation

The airplane relied on ILS and VOR/DME electronic navigational aids at both Pamplona and Barcelona airports. While on approach to the latter, it also received radar vectoring.

1.9. Communications

1.9.1. *General information*

The aircraft was in radio contact with various ATC facilities. Of particular interest were the communications it had with approach control and the towers at Pamplona and Barcelona airports. A transcript of said communications is consistent with what was recorded on the cockpit voice recorder (CVR).

1.9.2. *Communications with Pamplona airport ATC*

It was learned from the conversations recorded on the CVR that at 10:54:24, during the approach to Pamplona airport, the controller informed the accident aircraft (call sign ANS-8400) that the wind was from 300° at 14 kt, adding that there was «recent snow», later clarifying this by saying that the runway was covered in a «layer of snow that melts easily».

Moments before landing, and on the same frequency, a conversation was recorded between a signalman who was checking the condition of the runway and the airport tower, in which the signalman reported «there is a two-centimeter thick layer of snow that melts when you step on it».

Seconds after the accident aircraft landed, once it was parked, the tower informed other traffic, also on the same frequency, that it was snowing lightly and that the temperature was 1 °C and the dew point 0 °C.

For the ensuing flight to Barcelona, the accident aircraft was assigned call sign ANS-8041. The transcript of the communications between the tower and the aircraft confirmed that the flight was cleared for takeoff at 11:26:46. It also revealed that the runway in use was 33, that the wind was calm and that the initial climb level authorized was FL140.

1.9.3. *Communications with Barcelona airport ATC*

The communications held by the aircraft with Barcelona airport ATC are summarized in the next table:

Time	Station	Aircraft position	Message content
12:22:55	ANS-8401	On approach to runway 25R	Reports problem with the landing gear.
12:23:11	Approach	Going around	Assigns holding pattern above RULOS at 3,500 ft., acknowledged by traffic.
11:30:28	ANS-8401	Above point RULOS	Declares emergency and warns that they will have to land at Barcelona without nose gear. Requests assistance from fire fighters.
12:32:22	Approach		Coordinates with tower on possibility of coating runway with fire fighting FOAM, but aircraft cannot wait the estimated half hour needed to apply it.
12:41:00	Approach		Vectors aircraft in to aid it in capturing ILS localizer and transfers it to tower.
12:41:23	ANS-8401	LOC- ILS	Notifies tower of LOC capture.
12:41:59	Tower		Directs it to continue with approach. Reports wind from 280° at 11 kt.
12:42:41	Tower	On final	Authorizes landing and confirms that fire fighters are standing by next to runway 25L.
12:44:40	Tower	On final	Apparently their front gear is down.
12:45:46	Tower	On short final	Their front gear is not down.
12:47:09	ANS-8401	On the runway	We are on the runway. We are going to evacuate.

1.10. Aerodrome information

1.10.1. *Pamplona airport*

The airport in Pamplona has a single 2,207 m. long runway on an orientation of 15/33. It is at an elevation of 1.504 ft. The runway has a 0.52% gradient with the 33 threshold being higher than the 15 threshold. There is no taxiway, meaning that access to the threshold is via the runway itself.

The aerodrome is controlled, with its control zone (CTR) defined over a 6.5-NM radius and the aerodrome traffic zone (ATZ). It has the following navigation aids: VOR-DME, NDB and ILS-CAT I for runway 15.

On average, the airport has snow twelve days a year.

The airport has a contingency plan for winter ice and snow storms that includes a procedure for removing snow and ice.

The protocol defines a contaminated runway as, among other criteria, the accumulation of melted, dry or wet snow equivalent to a water thickness of 3 mm. The goal of cleaning operations is to prevent the accumulation of melting snow, in particular, in excess of 12.7 mm.

The procedure describes the actions to be taken by the Airport Weather Office, the Scheduling and Operations Specialist and the Movement Area Specialist (signalman). A block diagram illustrates the decision tree in the event that "A thick layer of snow or ice that affects operations (or coefficient <0.4)" is covering the runway. The diagram does not consider the presence of slush, though an adjoining table indicates the maximum contaminant thicknesses allowed for operations as 12.7 mm of slush, 50.8 mm of dry snow or 24.5 mm of wet snow. A note at the bottom of the table says that these are "approximate values for the maximum contaminant thickness allowed for operations".

Although the AIP states that no de-icing services are available for aircraft, it describes in its protocols that handling equipment is available to provide these services.

The equipment available on hand at the airport for maintaining the runway includes a surface friction tester, snow-removal plows and urea applicators.

Information on the condition of the runway is disseminated via SNOWTAMs and NOTAMs, as well as through the airport's ATC services.

Airport management reported that snow did fall at 09:00 on the day of the accident. It was removed using the snow-removal equipment and urea was applied in anticipation that the precipitation could be heavier than it actually was. It also reported that the condition of the runway was checked prior to the arrivals of scheduled flights (which were arriving on time with the runway wet), and that the parking area was completely free of snow. The runway was wet when flight ANS-8401 departed en route to Barcelona.

The investigation could not confirm whether the runway braking action was measured, whether it was made public via ATIS, NOTAM or SNOWTAM, or the exact times when the runway was cleaned. The crew did report, however, that during their stopover the snow removing equipment was in operation.

1.10.2. *Barcelona airport*

Barcelona's El Prat Airport[3] is located to the south of the city, next to the sea, and is at an elevation of 12 ft. It has three runways, designated 25R-07L, 20-02 and 25L-07R. The first two cross each other.

[3] Image taken from Google Earth.

Figure 8. Barcelona airport

The accident aircraft landed on runway 25L, which is 2,660 m long and 60 m wide. The elevation of the threshold is 8 ft. This runway has a convex profile, with a slight uphill the first 250 m, a zero gradient in its central part and a slight downhill the final 250 m.

Runway 25L has a PAPI glide slope visual aid and a CAT III ILS. Both the visual and the ILS slope have a 3° gradient.

As published in AIP-Spain, appendix 3 shows the instrument approach chart for runway 25L.

1.11. Flight recorders

1.11.1. *Cockpit voice recorders (CVR)*

The aircraft was equipped with a solid-state memory cockpit voice recorder (CVR) with a maximum recording time of 120 min.

Laboratory processing of the recorder yielded four audio tracks corresponding to the captain's microphone, the copilot's microphone, the area microphone and the fourth channel, which is a combination of the first three.

The recording time (120 min) included the airplane's arrival at Pamplona airport (flight ANS-8401), its stopover at said airport while the airplane was energized and the accident flight (flight ANS-8401).

The following table shows a summary of the most relevant conversations involving the accident as recorded on the track that combines the other three channels. The (local) time shown in the first column corresponds to that recorded by the ATC recording systems after synchronization with the time stamps on the CVR.

Time	Message
10:52:17	Pamplona tower tells signalman inspecting the runway if he can clear the runway.
10:52:19	The signalman replies: "I'll report runway clear in half a minute and tell you the condition".
10:52:36	The tower tells him that the snow plow cannot enter the runway or the taxiway at that time and to clear the runway.
10:50:57	The tower clears airplane to land on runway 15, reports wind 300/10 G16.
10:51:58	The airplane acquires the localizer.
10:53:24	The signalman reports "Runway clear. There's a 2-cm thick layer of snow that melts when you step on it".
10:53:37	The tower confirms the landing clearance and reports data for runway 15: "Overcast at 1000 ft, layer of snow that melts very easily".
10:55:34	The captain takes control of the airplane.
10:57:33	Landing completed.
10:57:34	Crew says: "We're down. Getting off is another story." "Sure is snowy here".
10:58:12	The crew does the parking checklist and says: "Parking checklist".
11:02:22	The crew is heard saying "...de-icing equipment we have here is... Type 1, 40%-60%".
11:02:37	Control tells another aircraft that "the weather is improving a lot".
11:03:52	Control informs another aircraft: "RWY 15, 310°/6kt G14, 3500m snowing slightly sct 800 ft, o/cast 1,200 ft 1 °C/0 °C QNH 1,010 TL 75".
11:08:31	The crew says; "Fuel?" "We're set".
11:09:07	Crew goes over takeoff briefing.
11:09:37	Passengers boarded.
11:12:27	The crew comments on the ice and water and says, "Ample performance margin, little weight".
11:14:42	Cleared by tower to start engines.
11:15:27	Captain goes out to look at ice.
11:19:07	Crew performs start-up checklist.
11:19:42	Crew requests passengers to turn off mobile phones and other electronic devices.

Time	Message
11:22:37	Cleared for takeoff on runway, tower reports calm winds.
11:23:27	Crew says: "ATC clearance to BCN".
11:26:52	Cres says: "Ready for TO. TO clearance".
11:27:27	Crew says: "V1, Vr".
11:27:37	Crew says: "Positive rate".
11:27:47	Gear up.
11:30:57	FL180 reached.
11:38:27	FL 200 reached.
11:43:27	FL 220 reached.
11:50:42	The copilot takes the controls.
11:57:27	Crew requests descent, ATC clears them to descend to FL 130.
12:12:27	They reach 8000 ft.
12:14:27	Control tells them: "Complete ILS to 25R".
12:16:42	ILS glide slope captured.
12:17:07	Wind 290/11.
12:19:12	The captain takes control of the airplane.
12:19:27	Gear problem identified, hold at 3,000 ft. Passengers moved to last rows.
12:21:57	Flight attendants notified of emergency.
12:32:42	Control offers foam and asks about fuel range. Crew replies 15 min.
12:41:57	Control authorizes emergency landing on runway 25L, reports wind 211/08.
12:46:47	Main landing gear touches down.
12:46:54	Nose touches down.
12:47:06	Airplane stops.

The CVR also recorded tense conversations between the Pamplona airport tower and other traffic and with different ground vehicles, due to the presence of snow-removing vehicles, on the runway prior to the arrival of certain flights and because some airplanes were about to lose their slot due to de-icing operations.

1.11.2. *Digital Flight Data Recorder (DFDR)*

The aircraft was equipped with a digital flight data recorder with a 128 word-per-minute recording speed. Only a few flight parameters from the Pamplona-Barcelona leg were obtained.

From the information analyzed, of note is the 4.6° down angle at the end of the landing run in Barcelona. The remaining parameters are consistent with a normal flight and landing.

1.12. Wreckage and impact information

After landing, the aircraft remained centered on runway 25L between taxiways G-4 and G-5, within the first third of available runway.

At 13:30, that is, 43 min after landing, the nose of the wheel was lifted with help from a crane and at 14:40 the aircraft was towed from the runway.

During the airplane's landing run, the front wheel well doors detached after receiving several scratches to their bottom edge. The hinges and anchors on the doors broke. The aft doors, the VHF antennas and the fuselage skin surrounding the open wheel well were also slightly scratched.

Three pieces of ice fell from the wheel well, weighing a total of 2 kg.

The post-accident inspection was not able to determine which tracks corresponded to those left by the main gear legs upon landing. Two parallel tracks were noted, however, some 214 m long and corresponding to the area of the front gear that had dragged on the runway, while supported by the heads of the actuators for the main doors of the front wheel well.

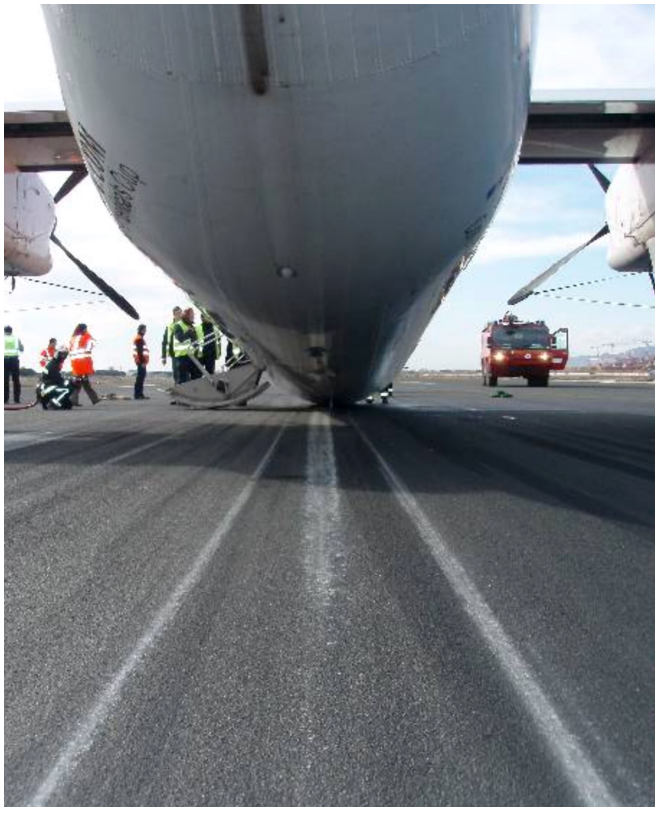

Figure 9. Drag marks on the runway

Another mark was found parallel to the above, wider and much shorter, indicating where the bottom part of the nose and the aft doors on the front gear had dragged along the runway.

The inhibition switch was found actuated and the lid that covers the control lever used to lower the main landing gear in an emergency was found in the down (open) position.

1.13. Medical and pathological information

Not relevant to the investigation.

1.14. Fire

There was no fire.

1.15. Survival aspects

Both the flight attendants and the passengers had been notified of the emergency and prepared for the type of landing.

The emergency evacuation was conducted on the runway. There were no incidents during the evacuation, which was completed normally.

1.16. Tests and research

The day following the accident, full operational tests of the front gear were conducted, consisting of performing two retraction and extension cycles of the gear using both the normal and emergency procedures with the aircraft lifted on jacks.

The results were as follows:

- In the first cycle, with the inhibit switch actuated, the leg retracted normally, it did NOT extend using the normal procedure and it DID with the alternate method.
- In the second cycle, with the inhibit switch in NORMAL, the leg retracted and extended properly using the normal procedure.

The inhibit switch was verified to be in the INHIBIT position and that the auxiliary (electric) pumps on both hydraulic systems were on and that the arming control that serves to steer the tiller was disconnected.

It could not be determined whether qualified technical support was provided at Pamplona airport, given the adverse meteorological conditions present.

The conversations recorded on the CVR indicate that the airplane was de-iced with type 1 fluid at a 40% or 60% concentration, but it is not known whether the inside of the wheel well was inspected.

1.17. Organization and management information

The aircraft's Flight Manual, in Section 1, page 11, states that the runway should normally be free from snow on takeoff and landing. In the event that the runway is contaminated, the maximum allowed water depth equivalent is 15 mm.

It also establishes a maximum contaminant depth of 6 cm. A contaminant depth of 2 cm with a density of 0.75 gr/cc is equivalent to 15-mm deep liquid water.

It further stipulates that when operating on snow- or slush-covered runways, that the front wheel well doors be checked from the outside for ice accumulation. If ice has formed, it should be removed by spraying with special de-icing fluids.

In the procedure for taking off from snow- or slush-contaminated runways, the manual specifies that consideration be given to delaying retracting the gear so as to blow away any ice deposits that may have formed on the landing gear.

It likewise states that the center of gravity must be aft of 23% MAC when taking off after de-icing so as not to diminish the efficiency of the elevator.

The procedure also specifies that when flying in a holding pattern in icing conditions, both the landing gear and the flaps must be retracted.

The procedures in the Operations Manual also consider cold weather operations for properly certified aircraft. These procedures list that areas such as the landing gear, the wheel well doors and the brakes are critical when flying in adverse weather. Along these lines, it specifically stipulates that the landing gear blocks, the hydraulic lines, all the microswitches and the wheel well hinges be free from snow, slush and ice.

1.18. Additional information

1.18.1. *Crew statements*

The crew reported that all three flights made that day had been in icing conditions and that the de-icing systems for the engine air intake, propellers and wings were turned on (the temperature was below 5° and there was precipitation).

They also noted that they landed on runway 33, which was slippery, and that during the landing in Pamplona the temperature had been approximately 0 °C and it was sleeting[4].

[4] Slush or sleet is a mixture of water and snow with the consistency of a thick liquid and a density of about 0.78 gr/cc.

They also reported that the runway was cleaned and two other airplane movements took place during their stopover.

While taxiing for takeoff, the taxiways and runways were clean and they did not pass over any slush.

The pre-flight inspection was made by the captain, who found some ice on the nose leg, which he removed by hand.

They also noted that during the takeoff, the GPWS "TOO LOW - GEAR" warning sounded for an instant.

They did not encounter any precipitation en route to Barcelona, though they did fly through clouds at 8,000 ft or 9,000 ft (their FL was 220). The outside temperature was around –33 °C.

When they actuated the gear lever prior to landing in Barcelona, the following light configuration appeared:

AMBER (Doors open)	AMBER (Doors open)	AMBER (Doors open)
	RED (gear not locked)	
GREEN (gear down and locked)		GREEN (gear down and locked)

During this time period, they heard a very loud noise and felt vibrations coming from the area of the nose gear. They maintained a speed of 160 kt until they were 4 NM away from runway 25R.

They cycled the gear a second time, during which they heard the gear retract normally and extend like before (red nose gear light), at which point they went around.

They attempted the normal procedure a third time, with the gear retracting normally once again and the red nose gear light coming on when lowered. They reported the gear problem to the tower and proceeded to the hold area as instructed to perform the alternate (emergency) gear release procedure.

After completing the emergency procedure, they noticed that the three green lights in the floor compartment (where the lever-actuated cable that goes to the front gear is housed) were on for the main gear but not for the nose gear.

They finally declared an emergency and asked the flight attendants to move the passengers to the rear of the airplane. They then reviewed the emergency procedure with the flight attendants during the approach.

Once on the ground the copilot opened the normal door for deplaning the passengers (1L) and went outside to help passengers exit the aircraft.

The airport's emergency services were already at the scene when the airplane came to a stop. There was no panic during the evacuation.

2. ANALYSIS

In this accident it is interesting to analyze separately the different environments in which the airplane operated, and which ultimately resulted in an emergency landing with the nose gear retracted.

First, we must consider the circumstances surrounding the landing at Pamplona airport and the stopover there. Second, a review of how the dispatch, takeoff and ensuing climb of the airplane on the flight to Barcelona progressed is appropriate. A third point to address is the ice formation process. How and when did it appear? Last is an analysis of the cruise phase of the flight and the subsequent landing at Barcelona airport, followed by the actions that are subject to improvement so as to avoid a recurrence of this event in the future.

2.1. Landing and stopover at Pamplona airport

Both the weather information provided by the State Weather Agency and that reported by the airport tower agreed in noting that it was or had been snowing at Pamplona airport shortly before the airplane's arrival, and that conditions were favorable to ice formation with air temperatures of 0° to 1 °C and dew points of 0 °C.

The information provided by airport officials regarding the state of the runway, taxiways and parking area indicated, without going into more detail, that the surfaces over which the airplane taxied were clean but wet.

The crew, however, noted during the landing that the runway was contaminated with slush. Among the conversations recorded on the CVR, there were some between the airport tower and the signalman and between the tower and other traffic indicating that there was a 2-cm layer on the runway that melted easily when stepped on. The thin layer being referred to was the slush, and if there really was a 20-mm layer of slush and this amount was accurately measured, then this represented marginal, or even prohibited, operating conditions. The flight manual limits for the accident airplane set a maximum of 15 mm of slush.

Similarly, the airport's own protocols for cleaning the runways establish an operating maximum of 12.7 mm of slush, though it does qualify this limit as "approximate".

Inconsistencies were observed with that day's procedural practices. During the investigation, serious doubts emerged as to whether airport officials are cognizant of the fact that a thin layer of easily melting snow is not irrelevant and poses a serious risk to operations, especially if it exceeds allowable thicknesses. The maximum operating limits, therefore, must be clearly specified. Officials must also understand that even conditions within limits can pose a significant risk to operations.

An analysis of the sound files recorded on the CVR revealed that the landing run at Pamplona airport lasted 25 s, while the landing run at Barcelona airport lasted 17 s. Although the time used to brake depends on many factors, and not just on runway conditions, it can be used as a measure of whether a runway offers better or worse braking conditions. Along these lines, the crew's statements following the landing regarding how taking off would be more difficult than the landing, also gives an indication that the conditions on the runway were far from desirable.

During the investigation it could not be positively established whether or not the tower informed other aircraft of the exact conditions present on the runway.

With regard to the preparation of the flight to Barcelona, the CVR analysis also revealed that the crew took an interest in the type of de-icing fluid that was being used and its composition, and that the captain went outside to check whether there was ice in the landing gear area, which there was and which he removed by hand, as he stated. This action is consistent with the stipulations in cold weather procedures, which require that the area around the front gear wheel well doors be checked *externally* for the possible presence of ice.

It is very likely that the captain did not look at the wheel well thoroughly, since this is not required by the procedure. A careful inspection of the wheel well requires bending down to a height below 60 cm and looking up, as well as having a flashlight to light the area to be inspected.

The net result of this is that if there was ice inside the wheel well, it was very unlikely that the captain would have been able to detect it. Such an exhaustive check of the wheel well would have required the presence of specialized personnel using the appropriate means.

As a result of the above, it may be concluded that there was very probably snow or slush on the runway when the airplane landed at Pamplona airport. There are indications that some of this snow or slush could have remained lodged in the wheel well without this occurrence being noticed, given that a rigorous inspection of the entire wheel well was not performed, nor were the proper personnel or measures available to do so.

2.2. Dispatch of flight ANS-8401, takeoff, climb and cruise

The crew completed all the checklists prior to takeoff and took into account a possible drop in performance due to the ice, though this was offset by the small load the airplane was carrying. During the investigation the crew reported that they did not travel over slush while taxiing or during the takeoff. Conditions improved considerably during their stopover at Pamplona airport in terms of increased visibility

and reduced cloud cover. The wind had also shifted, which allowed them to take off from runway 15.

It seems highly unlikely that the water, found in the form of ice in the wheel well, would have entered the well on takeoff, since the statements by the crew and airport officials make it clear that the runway was clean during that operation.

The airplane took to the air after a normal takeoff run. The crew quickly retracted the gear. Since they were unaware of the possible contamination in the front gear, they did not consider the desirability of leaving the gear down so as to ventilate it and allow any deposits to drain, as specified in the procedures. At any rate, the airplane climbed quickly and in a few minutes it was at altitudes where the temperature was well below 0 °C, which not only made de-icing impossible, but in fact promoted new ice formation due to ambient moisture.

That the gear was retracted immediately after takeoff is known because when "GEAR UP" was selected, the acoustic warning issued by the Ground Proximity Warning System indicating that the gear should be lowered due to the low altitude (TOO LOW - GEAR) sounded and was recorded. This GPWS warning should not sound on takeoff, since it is intended to alert only during the landing phase. The alarm should sound when descending below 500 ft at less than 178 kt, the purpose being to alert the crew to a possible oversight in not lowering the gear. On takeoff, the signal is inhibited for a certain length of time (the warning is linked to timers in the ground/air sensors). It is possible that the ground/air sensors located in the landing gear legs were also contaminated by slush, resulting in the spurious alarm.

The available weather information indicated the possibility of clouds between 2,000 ft and 9,000 ft. According to the crew, they encountered clouds between 8,000 ft and 9,000 ft. In any event, even if there had been excessive ambient moisture, it does not seem possible that the moisture in these clouds would have penetrated the front wheel well (which was closed) and formed ice deposits in the short amount of time required by the aircraft to traverse the cloud layer.

While en route to Barcelona, the aircraft flew at FL220 during the cruise phase. There were no clouds at this level and the outside air temperature was –35 °C, meaning it is unlikely that moisture from the outside would have entered the nose wheel well during this phase.

2.3. Process of ice formation on the leg

In light of the above considerations, the most likely scenario seems to be that as the airplane travelled over the slush at high speeds during the landing in Pamplona, the slush was thrown upward by the centrifugal force into the wheel well, where it then

solidified. The aft doors could have funneled the flow of slush, thus facilitating its entry into the well. The small height above the ground of the lower fuselage in the nose section of the airplane is propitious to channeling any splattered liquids. The distance from the wheels to the wheel well is only 25 cm. On the other hand, the greater height of the engine nacelles above the ground impeded the entry of water into the main landing gear legs.

Once the water penetrated inside the wheel well, it remained there for the duration of the stopover. A portion of the water that thawed most likely flowed down and froze on the nose wheel leg while the airplane was parked. This is the ice that the captain removed with his hand.

Some of the slush that had accumulated in the gear housing undoubtedly continued to thaw during the takeoff, climb and initial cruise phase of the flight to Barcelona. At zero-degree temperatures, any energy that is added to the snow or slush acts to thaw it, as the small ice crystals that comprise it absorb the latent heat of fusion. The melting action affects not only the liquid water that thaws, but also that held by capillary action and surface tension in the slush.

The retraction of the gear proceeded normally, with the front wheels going into the wheel well with the doors closed. Inside the wheel well there were several sources of heat. The tires were very hot after taxiing, there was warm air being supplied from the cockpit, and the hydraulic lines and landing gear and door cylinders were also giving off heat. In an atmosphere with temperatures slightly above freezing, and aided by the heat emitted by the aforementioned components, the ice started to thaw and flow. The surface tension of the dirty thaw water held the water on the surface of the leg's aluminum alloy at a very low temperature. The transfer of the latent heat of fusion from the liquid water to the aluminum on the leg and to the surrounding air, both of which were colder, froze the water once again, turning it into ice. The cooling was accentuated after takeoff once the airplane started to climb.

Figure 10. Detached ice

In considering the nose gear retraction sequence (Figure 7), we see that the body of the leg rotates forward as the drag strut bends, only to unfold again in an approximately horizontal position alongside the retracted leg, exactly in the area of the gear up locking

mechanism. The body of the leg is made of an aluminum alloy with a very high heat capacity.

When the airplane reached high flight levels, it also encountered very low ambient temperatures that eventually finished freezing all of the water that was still in a liquid state.

The ice build up on the leg enveloped the drag strut, making it stiff and unable to bend when the unlocking actuator was activated or when the lever that operated the alternate system was pulled, the hydraulic force not being sufficient to break the ice.

2.4. Landing of flight ANS-8401 in Barcelona

The crew was not aware of the fault in the nose gear until they were on the approach flight path and they tried to lower it. They reacted by aborting the landing maneuver, in keeping with the procedures defined for that type of emergency. All of this was done in accordance with ATC instructions.

After several unsuccessful attempts to lower the gear while in the holding pattern, the crew opted for an emergency landing without the nose gear. At that time there was no presumed cause for the failure of the gear, and given that the aircraft had been flying over Barcelona for some 25 min, the decision to land seems to have been the most appropriate.

Atmospheric conditions were good and the temperature was around 11 °C. As they were landing, the crew received confirmation from ATC that the front gear was not lowered, though the front wheel well doors were open.

The aircraft eventually landed in a 15° down flaps configuration with both main gear legs lowered, the front gear leg retracted and the front wheel well doors open. The captain had ordered the passengers moved to the last rows of the passenger cabin, as specified in the emergency procedure in an effort to move the center of gravity back and take weight off the nose of the airplane.

The landing with that configuration proceeded normally until, at a reduced speed and before losing the aerodynamic force of the horizontal stabilizer, he let the nose drop gently on the runway.

The nose initially made contact through the edges of the front wheel well doors, the hinges of which broke before the doors detached and fell to the runway. The nose then rested on the head of the actuators that open the doors until, in the final moments, the head scraped lightly against the skin of the fuselage and of the rear wheel well doors.

Figure 11. Sound spectrum of noise scraping runway

The drag marks left by the landing were 214 m long. The CVR recorded a drag duration of 11.75 s. Assuming a constant deceleration over the final few seconds of the landing run, it may be estimated that the nose dropped when the speed was approximately 70 kt. Figure 11 shows the frequency spectrum for the noise recorded as the nose was scraping the runway.

Although the captain did not have steering control of the nose wheels, he could exert lateral control until the last moment through asymmetric braking of the main gear wheels. The aircraft came to a stop in the center of the runway some 600 m away from the threshold of runway 25L after making a short landing run using the minimum distance possible, in keeping with the aircraft's available performance.

Perhaps if the crew had suspected during the flight that there was ice in the wheel well, the ice could have been thawed by flying lower or to another, warmer aerodrome or environment, since the time spent flying in the holding pattern at 3,500 ft where the temperature was some 3 °C did not promote the melting of the ice.

The full operational tests conducted on the gear the following day, when all traces of ice had disappeared, confirmed that it, in fact, had caused the gear to lock.

2.5. Corrective actions

Although this Commission is unaware of similar prior accidents, it would be advisable for the manufacturer to weigh the possibility of installing deflectors to redirect any splashing water, as is done on other airplanes, or even of completely closing the front wheel well to prevent foreign objects from entering it.

It would also be worthwhile for the manufacturer to warn operators exposed to this type of scenario to exercise extreme caution when checking for ice and to consider the potential for slush to accumulate inside the front wheel well housing when operating on runways that may be contaminated.

As for the airport officials' actions, it remains unclear who exactly assumed the responsibility of keeping the runway in service, the signalman or the controller. It would

be advisable to have the airport procedures be unmistakably clear in defining when a runway should be considered as inoperative by specifying objective, and not approximate, criteria, as well as which person(s) must make the decision.

Very cold climates are not the most susceptible to runway contamination. Dry, powdered or packed snow do not pose the same risks as wet snow, or especially slush. These more dangerous conditions are usually present when the air temperature is fluctuating around the freezing point, or with colder ambient temperatures but greater asphalt temperatures due to solar radiation. The half-inch rule (12.7 mm of slush) only takes into account the degraded performance of airplanes, but reality has shown that less slush than that can contaminate an airplane from the effects of splashing. Therefore, regardless of the thickness of the slush layer, the airplane should be checked for contamination after taxiing over snow.

3. CONCLUSION

3.1. Findings

- When the aircraft landed at Pamplona airport, there was slush on the runway and the temperature was between 0° and 1 °C.
- Half an hour after landing it took off for Barcelona airport.
- During its stopover at Pamplona airport, it was de-iced.
- The captain did the pre-flight inspection and found pieces of ice in the front gear leg but he did not look inside the wheel well. He had neither specialized assistance nor the equipment available to do the inspection.
- After taking off for Barcelona, the crew quickly retracted the gear.
- On the flight to Barcelona, the aircraft climbed rapidly to cruise altitude FL220, passing through some clouds between 8,000 ft and 9,000 ft.
- At cruise altitude FL220 there was no humidity in the atmosphere and the temperature was –35 °C.
- On approach, when the crew selected the gear down prior to the landing in Barcelona, the front gear did not lower and the aircraft had to go around.
- After repeated attempts to lower the gear using the normal and alternate procedures, the crew made the landing with the front gear retracted.
- The landing was smooth and the airplane stopped in the center of the runway, dragging the nose the last 214 m of the run without a loss of control.
- The 19 passengers and 4 crewmembers evacuated the crew without incident with assistance from emergency personnel.
- The aircraft was slightly damaged.
- The front landing gear was prevented from extending by pieces of ice.
- Water penetrated the wheel well in the form of slush upon landing at Pamplona airport.
- The gear was jammed by the blocks of ice that had formed when the slush that remained in the wheel well froze.

3.2. Cause

The cause of the accident was the inability to extend the front landing gear, which was jammed after slush, which had entered the wheel well while landing on a contaminated runway at Pamplona airport, froze into several pieces of ice.

The slush was not detected during the pre-flight inspection made prior to takeoff.

4. SAFETY RECOMMENDATIONS

REC 13/10. It is recommended that AENA clearly define in each airport's procedures the objective criteria for declaring a runway as not in service when it may be contaminated by ice or slush, along with who must make that determination.

REC 14/10. It is recommended that DENIM AIR instruct its crews and maintenance personnel on the importance of reliably checking that an airplane is free from snow, slush and mud, especially after taxiing on runways that may have been contaminated.

REC 15/10. It is recommended that BOMBARDIER study the possibility of modifying the gear design so as to avoid having contaminants penetrate the gear.

REC 16/10. It is recommended that BOMBARDIER define what it regards as the most effective way of inspecting the front wheel well so as to ensure that any contaminants that may be lodged inside can be detected.