Accident Investigation Board Norway

REPORT

SL Report 2007/25

REPORT ON THE SERIOUS INCIDENT ON HARSTAD/NARVIK AIRPORT EVENES ON 25 NOVEMBER 2004 INVOLVING FLIGHT MYT6286 AIRBUS A320 REGISTERED G-CRPH OPERATED BY MYTRAVEL AIRWAYS UK

Submitted
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REPORT ON THE SERIOUS INCIDENT

Designation of type:	Airbus A320
Registration:	G-CRPH
Owner:	HAIR Ltd
Operator:	MyTravel Airways (UK)
Crew:	2+4
Passengers:	116
Accident site:	Harstad/Narvik Airport Evenes (ENEV). West side of departure runway 25, position 68°29’18’’N 016°40’42’’E.
Accident time:	Thursday 25 November 2004 at 2236 hrs

All times given in this report are local time (UTC + 1), if not otherwise stated.

NOTIFICATION

The Duty Officer of the Accident Investigation Board Norway (AIBN) was notified at 0100 hrs on 26 November 2004 by the Air Traffic Controller at Harstad/Narvik airport Evenes (ENEV). The incident investigation was initiated immediately. The Director of the AIBN was also notified by MyTravel Airways Chief Pilot at 0830 hrs the same morning.

SUMMARY

MYT6289, an Airbus A320 with registration G-CRPH, was aligned up for take off on runway 35 at ENEV. During the application of take off power, there was an asymmetric build up of engine thrust causing the left engine to lag the right engine. This caused a yawing moment that resulted in a loss of directional control. The aircraft yawed approximately 40° and departed the partially snow covered runway in spite of the crew selecting engine idle, applying nose wheel steering and braking. The aircraft continued to move forward at a slow speed off the paved area and onto an area of snow-covered soft ground. The nose wheel created a large furrow as the aircraft came to a stop in snow and soil at an angle of approximately 40° to the runway centre line. The tail and the nose of the aircraft were 12 m and 35 m from the runway edge respectively. The distance from the runway centre line to the edge was 22.5 m.

Damage to the aircraft was limited to a punctured left nose wheel tyre, a separated and deformed left nose wheel hubcap and a broken nose leg taxi light.

The last reported friction numbers for runway 17 were 30-32-32 measured with Skiddometer with high pressure tire (BV-11/SKH). The runway was covered with up to 8 mm of loose dry snow upon sanded ice.

The lagging engine rpm of the left engine was probably caused by icing on the fan blades during the taxiing and holding before take off.

AIBN has forwarded four safety recommendations.

1.1 History of the flight

1.1.1 The flight was scheduled to depart at 2100 hours for the return trip to Norwich, UK. The crew arrived at the airport 1 hour prior to this, following a 1hr 15 min journey from the company-provided accommodation.

1.1.2 On arrival at the airport the flight plan and briefing documents were not immediately available, so the flight crew proceeded to the aircraft to conduct their pre-flight preparation. There had been light snow fall during the day and there was very light snow falling at the time. The crew obtained the airfield operating conditions from the airfield Automated Terminal Information Service (ATIS). The crew wrote the information down on the back of the weather information and NOTAMs they had received with the briefing documents which had been delivered to the aircraft. It was annotated “Q” (ref. item 1.7.4). The crew had also included a note of “8 mm dry snow”.

1.1.3 The minimum braking action required for take-off, as defined in the company Standard Operating Procedures (SOP) A320/1/330 Standard Operating Procedures – Take-Off, section 3.03.12, page 1 (ref. Appendix D), is “MEDIUM” in all three sectors of the runway. The braking coefficients given in the ATIS were checked by the Commander and First Officer by referring to FCOM Vol. 2, Section 2.04.10, page 11, SEQ 001, REV 21 Special Operations (ref. Appendix E) and MyTravel UK OM Part A, section 8.2.4.12 Braking Action (ref.Appendix H-2). From these documents both pilots agreed that a braking coefficient of 0.29 or greater was required. 0.30 and greater satisfied the minimum braking action of “MEDIUM” as required by the MyTravel Airways SOP.

1.1.4 The crew, referring the FCOM Vol. 2, Special Operations, Fluid Contaminated Runway, Section 2.04.10, page 1, SEQ 001, REV 32, paragraph 1 (ref. Appendix F), concluded that with 8 mm of dry snow a “WET” take-off performance calculation was required.

1.1.5 There was a discussion between the pilots as to whether the Commander should fly the leg back to Norwich and also perform the taxiing, considering the weather conditions. The pilots decided to continue with standard company procedure, i.e. pilots operating alternate legs, and for the First Officer to operate the return leg.

1.1.6 Once aircraft preparation and boarding were completed, the aircraft was pushed back to the de-icing area. The crew was briefed about the procedure by the engineer as the local de-icing procedures did not appear in the company airfield brief.

1.1.7 The aircraft was de-iced with a one step procedure using Type II fluid. The details of the de-icing fluid and start time were passed over the radio to the crew and noted on the Computer Flight Plan.

1.1.8 At 2207 hrs a new friction measurement was performed and reported to Widerøes flight WIF638, a DHC-8, which was inbound for landing on runway 35. The friction values were reported as 35/26/24 for runway 35, and wind variable 5 kt or less. WIF638 accepted the values and landed normally at 2219 hrs and taxied in at taxiway D (ref. figure 6).

1.1.9 At 2210 hrs MYT6286 was informed by Air Traffic Control (ATC) about the new friction numbers for runway 35, reported as 35/26/24, with 0 to 6 mm of dry snow. The wind was reported as 180° 3 kt at the threshold south, and 340° 5 kt at the threshold north. MYT6286 informed ATC that they required a minimum friction number of 29. The airport personnel then initiated a new sanding of the runway north of taxiway D.

1.1.10 The Commander of MYT6286 was concerned about the de-icing holdover time and the time it would take to sand the runway and measure new friction numbers. The ATC assured the crew that they would "hopefully get it back up again to around 30 for the northern part". The MYT6286 crew was reassured by the exchange of messages that the runway surface would be suitable for departure.

1.1.11 At 2216 hrs MYT6286 was informed by ATC that the preliminary friction numbers showed an improvement to around 32, and that they would get full figures before take off. In the meantime the airport personnel would put more sand on the runway.

1.1.12 The aircraft was taxied by the First Officer from the De-icing Area for a departure from runway 35. He initially taxied towards taxiway D to backtrack the runway (see Figure 6). During taxiing at 2226 hrs MYT6286 was informed by the ATC that the braking coefficients for runway 35 were 32/32/30. The wind was reported as calm at the south, and 330° 10 kt at the north end of the runway.

1.1.13 The First Officer registered no unusual handling or braking problems during taxi out. The maximum speed attained was 15 knots. As the aircraft approached the end of the runway, the crew discussed which direction to make the turn around. Because of a runway turn-off to the left the crew decided a turn to the right was best with the aircraft initially turning to the left. About this time ATC passed a warning to the crew that the runway was very slippery beyond the displaced threshold.

1.1.14 Both pilots recalled that the end of the runway was significantly more contaminated than the runway they had taxied down. It was covered with a fine layer of snow, sufficient to obscure the runway markings. The First Officer reduced to a very slow taxi speed and reported no difficulties with braking. However, as he attempted to turn the aircraft there was no response to the nose wheel steering input and the aircraft continued straight ahead. He immediately stopped the aircraft and handed control to the Commander who was unable to turn the aircraft and stopped.

1.1.15 The crew requested extra sanding of this section of the runway and, following a very short delay, a sanding truck made a single pass right to left in front of the aircraft from the runway and along the closed taxiways F and Y (see Figure 6).

1.1.16 The Commander commenced the turn, and although he tried using asymmetric thrust, it was not required as the nose wheel steering was fully effective. The Commander retained control and lined up with the unlit runway centre line, moving forward clear of the more contaminated area. The Commander could see the runway centre line and designator markings through the fine layer of snow. The Commander then handed over control to the First Officer for take-off.

1.1.17 The Digital Flight Data Recorder (DFDR) data showed that the aircraft started turning at 22:34:58 hrs by use of the hand tiller with the rudder pedals at neutral. The No 1 engine was advanced slightly to assist the turn. At 22:35:41 hrs the turn was completed and the aircraft was brought to a halt on a heading of 354.7°.

1.1.18 The DFDR data show that the brakes were released at 22:35:58 hrs and the aircraft started to move forward. At 22:36:04 hrs the throttles were advanced progressively to a Throttle Lever Angle (TLA) of 33.75°. At no time were the throttles paused at part power to allow stabilization, nor were any engine ice shedding procedure carried out. Just prior to throttle advance, there was a step change in engine no. 2 N2 of 7 %. The no. 2 engine accelerated normally up to the commanded Engine Pressure Ratio (EPR) of 1.34375, the no. 1 engine EPR only achieved a maximum of 1.10547. The N2 increased, but remained 9 % lower than the no. 2 engine.

1.1.19 At 22:36:13 hrs both throttles were retarded to idle thrust at a ground speed of 10 kt and right rudder pedal input was initiated. There was no input to the brake pedals at this point. The aircraft continued to increase in speed up to a maximum of 22 kt and the heading deviation continued to increase.

1.1.20 At 22:36:18 hrs both brake pedals were fully applied and the aircraft came to a halt within 6 seconds and was at a dead stop at 22:36:24 hrs. At this time ATC was informed that the aircraft had slid off the runway.

1.1.21 At 22:36:41 hrs the park brake was applied. At this time the Commander was hoping that it would be possible to tow the aircraft back onto the runway. However, the arriving rescue personnel quickly assessed this option unrealistic.

1.1.22 At 22:47:48 hrs the no. 2 engine was shut down, followed by the no. 1 engine shut down at 22:47:53 hrs.

1.1.23 The aircraft departed the runway to the left on a heading of 313^{o} and came to rest with all wheels off the paved area in 25 cm of snow, approximately 125 m from the threshold lights of runway 35. (Figures 1 - 3). The aircraft's nose was approximately 35 m from the paved runway edge and the tail was approximately 12 m from the edge. There was no impact but a slow and steady deceleration. The nose wheels had been sufficiently deflected on leaving the paved surface that they were pushed to 90^{o} (Figure 2) from their normal position. The nose wheels had penetrated the frozen top layer, sinking into the soil. The momentum of the aircraft pushed it for approximately 8 m. The right main wheels had sunk into the soft ground but had sunk only 12 cm which was halfway up the tyre wall. The left main wheels did not sink in.

1.1.24 When the aircraft was stationary, the First Officer prompted the Commander to make a "CABIN CREW ON STATIONS" call to the cabin crew. However, the Commander felt that a "PASSENGERS AND CREW REMAIN SEATED" call was more appropriate and this was done.

1.1.25 The passengers, then crew, evacuated from the rear of the aircraft using normal aircraft steps and were transported to the airport terminal by buses.

1.1.26 ATC did not initiate the crash alarm based on the communication with MYT6286. However, the rescue leader ordered two fire trucks out to the aircraft, in addition to other rescue vehicles. One fire truck was standing by at the aircraft until the buses with passengers and crew had left for the terminal.

1.1.27 The First Officer's account of the Take-off

1.1.27.1 The First Officer allowed the aircraft to roll forward onto the clearer section of runway and then advanced the power levers to allow the engines to stabilise at 1.05 EPR, before selecting the FLEX[1] position. However, although he was confident that he did, the First Officer did not recall positively checking that the engines had stabilised before selecting FLEX power.

Figure 1. G-CRPH nose wheel sunk in the snow and soil.

1.1.27.2 Almost immediately the aircraft started to veer to the left and he became aware that he did not have directional control. The First Officer tried to correct the turn to the left and also remembers using the tiller to attempt to regain directional control with nose wheel steering but this was ineffective. During this time he had returned the thrust levers to idle, and with the aircraft moving towards the side of the runway he applied the brakes to no effect. The Commander then took control.

1.1.27.3 The First Officer stated that when applying power his hand was on the tiller as the aircraft was only moving at a few knots, similar to a fast taxiing speed.

1.1.28 The Commander's account of the Take-Off

1.1.28.1 The Commander taxied the aircraft to a clearer part of runway. He recalls that the First Officer advanced the thrust levers to stabilise the engines. At this time he looked outside to assess the runway centreline tracking, he did not notice the power setting. He believed the First Officer then set FLEX thrust and almost immediately the aircraft began to veer to the left. He was aware that the First Officer was trying to correct towards the centreline, with no effect. The First Officer then closed the thrust levers. The Commander

[1] FLEX power setting is a reduced take off power setting controlled by the aircraft management computer

took control and applied full right steering and maximum braking. The aircraft did not respond and departed the runway coming to a halt a short distance from the runway edge.

1.1.28.2 The Commander stated it was difficult to assess the aircraft position due to the surface covering of snow, but he felt confident that the main gear was on the paved surface. Based on his assessment of the aircraft position he decided to keep the engines running. It was only after ground assistance arrived that the extent of the runway excursion was apparent and the engines were shut down.

Figure 2. The nose wheel seen from rear.

Figure 3. Right main wheels.

1.2 Injuries to persons

Injuries	Crew	Passengers	Other
Fatal			
Serious			
Minor/none	6	116	

1.3 Damage to aircraft

1.3.1 The aircraft was slightly damaged. Conf. item 1.12.1 for details.

1.4 Other damage

The aircraft nose wheels ploughed an 8 m long, 1 m wide and 60 cm deep furrow in the soft soil adjacent to the runway. The furrow was caused by the nose wheel, which was twisted 90°, breaking through the frozen unpaved surface (Figures 2 and 5).

Figure 4. Furrow ploughed by the nose wheel.

1.5 Personnel information

1.5.1 <u>Commander</u>

Flying experience	All types	On type
Last 24 hours	4	4
Last 3 days	4	4
Last 30 days	45	18
Last 90 days	70	24
Total	10,900	2,980

1.5.1.1 The Commander held a current JAR-FCL ATPL(A) valid until 14 July 2005. He was rated on Airbus aircraft types A318/319/320/321/330. His last Proficiency Check was performed on 7 October 2004, valid until 30 April 2005. He held a UK Type Rating Examiner valid for A320/321 aircraft until 27 November 2006, and a Class 1 medical without limitations, valid until 2 February 2005.

1.5.1.2 The Commander completed Category C airfield simulator training on 3 November 2004, including the authorisation procedure for operating into ENEV.

1.5.1.3 The Commander stated that he felt fit for flight for the scheduled duty.

1.5.2 <u>First Officer</u>

Flying experience	All types	On type
Last 24 hours	4	4
Last 3 days	4	4
Last 30 days	22	22
Last 90 days	117	117
Total	6,200	117

1.5.2.1 The First Officer held a current UK National ATPL(A) valid until 12 October 2007, and a UK Instrument Rating (A) valid until 30 September 2005. He was rated on Airbus aircraft types A318/319/320/321. His last Proficiency Check was performed on 3 September 2004, valid until 30 September 2005. He held a UK Crew Resource Management (CRM) Instructor Rating valid until 31 March 2006, and a Class 1 medical with 3 VNL corrective lenses limitations, valid until 11 December 2004.

1.5.2.2 The First Officer had recently converted to type. His conversion course was completed on 25 August 2004, with line training completed on 6 September 2004.

1.5.2.3 All First Officers were required to perform a category C airfield training by a “self briefing” and to sign the computer flight plan to that effect. This had not been done by this First Officer.

1.5.2.4 The First Officer stated that he felt fit for flight for the scheduled duty.

1.5.3 <u>Cabin Crew</u>

There were four Cabin Crew. Two of these crew members were qualified as Cabin Supervisors.

1.6 Aircraft information

1.6.1 <u>General</u>

1.6.1.1 Airbus A320 is a medium range twin engine low wing turbofan aircraft developed and manufactured by Airbus Industrie. The cabin may seat up to 179 passengers.

1.6.2 Aircraft data

Manufacturer:	Airbus Industrie
Model:	Airbus A320
Airworthiness certificate:	Valid until 14 April 2007
Year of production:	1993
Serial number:	424
Total flying time, hrs:	36,661
Total number of flight cycles:	13,184
Engine type:	International Aero Engines IAE V2500-A1
Engine running time, hrs:	No 1 S/N V0323 2,129 No 2 S/N V0136 3,226

1.6.3 Maintenance

The aircraft was registered in UK and maintained in accordance with JAR 145. The aircraft had 574 FH since the last “A” check and 3,438 FH since the last “C” check. Examination of the technical log revealed no significant defects in the period 29 October to 25 November 2004. The main tyres and brakes were confirmed as being in good condition immediately after the event. The aircraft was serviceable on the date of the incident.

1.6.4 Mass and Balance

The aircraft had a take off mass of 62,600 kg with a Centre of Gravity (CG) position of 29 %. The maximum takeoff mass was 77,000 KG with a CG range of 18 -41 % Mean Aerodynamic Chord (MAC). Hence, the aircraft mass and balance were within limitations.

1.6.5 Fuel

The aircraft was loaded with 10,000 kg of JET A-1 fuel at the time of the incident.

1.7 Meteorological information

1.7.1 Weather observations from TWR

The wind had been varying by up to 26 kt during the day and early afternoon. There had been occasional snow showers reducing visibility down to 1,000 m. During the evening before and after the incident the wind was light, about 6 kt, with good visibility in light snowfall. The temperature remained around minus 4-5°C. The incident occurred during the hours of darkness.

1.7.2 TAF Information

ENEV 251100Z 251221 34010G20KT 9999 FEW015 SCT030 TEMPO 1524 0800 SHSN VV006=

ENEV 251400Z 251524 34010KT 9999 FEW010 SCT030 TEMPO 1524 0800 SHSN VV006=

ENEV 251700Z 251824 34008KT 9999 FEW010 SCT030 TEMPO 1824 0800 SHSN VV006=

ENEV 252000Z 252124 34008KT 9999 FEW010 SCT030 TEMPO 2124 0800 SHSN VV006=

1.7.3 METAR Information

ENEV 251950Z 34008KT 9999 –SHSN BKN030 M04/M06 Q1018

ENEV 25 2050Z 34006KT 9999 –SHSN SCT015 BKN030 M04/M06 Q1018

1.7.4 ATIS Information

ATIS Information “Q”. 1950Z 34008Kt 9999 -SNSH BKN 030 M04/M06 Q1018 Braking Coefficient RWY 17 34/32/32 measured at 1950Z.

ATIS Information “R”. 2050Z 35006Kt 9999 -SNSH SCT015 BKN 030 M04/M06 Braking Coefficient RWY 17 34/32/32 measured at 1950Z.

1.7.5 SNOWTAM Information

1.7.5.1 SNOWTAM 0090: (including decode)

A) ENEV *(Evenes)*

B) 11251950 *(Month Day Time (UTC))*

C) 17 *(Runway 17)*

F) 47/47/47 *(Deposits each runway 1/3rd 4 = Dry Snow, 7 = Ice)*

G) 8/8/8 *(Deposit depth in millimetres)*

H) 34/32/32/SKH*(Friction coefficient & measuring equipment)*

N) 487 *(Taxiway Deposits 4 = Dry Snow, 8 = Compacted & Rolled Snow, 7 = Ice*

R) 487 *(Taxiway Deposits 4 = Dry Snow, 8 = Compacted & Rolled Snow, 7 = Ice)*

T) 50 PCT (%) DRY SNOW ON SANDED ICE *(Plain language remarks)*

The SNOWTAM showed that the runway was covered with 8 mm of dry snow on sanded ice with friction numbers for runway 17 as 34-32-32 (MEDIUM) measured with Skiddometer (BV-11 with high pressure tire).

1.7.6 Weather information received by the crew

1.7.6.1 The crew had not received the company weather and NOTAM briefing folder on arrival at the airport as expected. However, they did receive Departure, Destination and Alternate airfield weather and NOTAM information from the Scandinavian Airline System (SAS) handling agent. No SNOWTAM reports were made available to the crew, although SNOWTAM 0900 issued 1950Z was valid. The crew did not request the SNOWTAM or any other details related to the runway status from ATC. However, the crew was kept updated by the ATC during start up and taxiing.

1.7.6.2 The crew did not receive the SNOWTAM as part of the briefing documents. The ATIS gave information about snow showers and runway braking action numbers. These were the same as on the SNOWTAM values. The ATIS information was in general agreement with the TAF and METAR which both indicated snow showers. These were also in agreement with the general weather situation during the day.

1.7.7 Meteorological expert weather review

1.7.7.1 AIBN is using a professor (from University of Tromsø, Norway, now retired) as a meteorological expert during investigations related to slippery runways on Norwegian winter operations in general. An extract from his report[2] is shown in Appendix B.

1.7.8 Runway preparation during the preceding hours

1.7.8.1 The parallel taxiway Y had been closed during the afternoon due to the runway and apron being prioritised for snow clearing. There had been some heavy snow showers accompanied by gusty wind during the day. This prioritising is in accordance with the snow clearing plan of the airport.

1.7.8.2 At 1800 hrs runway sweeping was initiated. After sweeping, the runway including the thresholds south and north was sanded. The runway preparation was concluded at 1830 hrs, when friction measurement (36-37-37) was performed and a runway report issued.

1.7.8.3 At 2010 hrs runway sweeping was again initiated. Following sweeping the whole runway was sanded. Based on experience, more sand was spread on the concrete thresholds since these areas were often extra slippery. Runway preparation was finished at 2030 hrs, runway friction measurements performed (34-32-32) at 2050 hrs and runway status reported to ATC. This was the basis for the 1900Z SNOWTAM report, even though the runway preparations had started 50 min earlier.

1.7.8.4 At 2210 hrs more sanding was performed on runway sections A and B, from taxiway D and northwards. This was based on a runway friction measurement performed at 2207 hrs which showed friction numbers of 24-26-35 on runway 17. This was just before WIF638 landed in order to improve the friction on parts A and B. This sanding was carried out to improve the friction level after a request from MYT6286 which had asked for a minimum

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[2]Reinhard Mook, Micrometeorological processes on a runway contaminated by frozen water, 2006.

friction number of 29 for take off. At 2226 hrs the new friction numbers were reported to ATC as 30-32-32 for runway 17.

1.7.9 Runway status, friction measurements and reporting before and after the incident

1.7.9.1 The friction measurements were performed with Skiddometer (SKH/BV-11) with high pressure tire. The measurements were carried out 3-7 metres on either side of the centre line from north to south and reverse. The measuring speed was 65 km/hr. Due to the turning radius and braking and acceleration in either end of the runway, the last 60 m from the runway thresholds were not measured.

1.7.9.2 Below are listed median values on each third of runway 17, parts A-B-C. The snow depth was reported in millimetres as measured by airport personnel. According to Norwegian regulations the snow depth for dry snow below 8 mm is reported as 8 mm on the runway report sheets and on SNOWTAM (see item 1.7.10.6):

- 1515. Sanded ice with 6 mm of dry snow. CF 34-30-32.
- 1830. Sanded ice (no snow). CF 36-37-37.
- 2050. Sanded ice with 3 mm dry snow. CF 34-32-32 (SNOWTAM).
- 2207. Sanded ice with 6 mm of dry snow. CF 24-26-35
- 2225. Sanded ice with 6 mm dry snow. CF 30-32-32 (MYT6286)
- 2234. Sanding in front of MYT6286's nose wheels to facilitate the turning of the aircraft into take off position. Light snow fall.
- 2236. MYT6286 runway excursion.
- 2311. Sanded ice with 8 mm dry snow. CF 29-29-27.

1.7.10 Norwegian regulations governing winter maintenance of runways

1.7.10.1 Norwegian regulations governing airport snow clearing, friction measurement and reporting are published in Aeronautical Information Publication Norway (AIP Norway[3]), as shown under items 1.7.10.4 and 1.7.10.5.

1.7.10.2 AIP Norway, AD 1.2, item 2.6.3 defines the acceptable conditions for the approved measuring devices. The SKH/SFH is approved for measuring on runways covered with up to 25 mm of dry snow and up to 3 mm of wet snow or slush. The acceptable conditions do not include 8 mm of dry snow on top of compacted snow as reported prior to the departure of the aircraft.

1.7.10.3 AIBN is working on a general report on incidents related to Norwegian winter operations and friction measurements. The investigations so far have led to 4 immediate safety recommendations, including a review of the acceptable conditions for the measuring

[3] Aeronautical Information Publication Norway, valid November 2004

devices. Conf. item 1.18.11.3. AIBN is reviewing further safety recommendations related to winter operations in the ongoing investigations.

1.7.10.4

2.4 Treatment

The surfaces of the movement area shall be treated so as to obtain the best friction possible, with special attention to the runway. To obtain better friction mechanical treatment, chemicals and sand are used. Close cooperation between the aerodrome operator and the aircraft operators are compulsory in avoiding chemicals that can harm aircraft.

2.5 Reporting

2.5.1 The international SNOWTAM format is used for reporting the winter conditions at the movement area. The format is described in ICAO Annex 15, Appendix 2.

2.5.2 The conditions at the movement area are reported to the ATS using a special format from which the ATS will issue a SNOWTAM.

Special attention should be made to the following:

G –Mean depth

The mean depth of the deposits of loose snow of slush reported under item F, is reported for each third of the runway as viewed from the threshold having the lower runway number. The depth is reported in millimetre to an accuracy of 20 mm for dry snow, 10 mm for wet snow and 3 mm for slush, and is rounded upwards which means that wet snow between 10 and 20 mm is reported as 20 mm. If the depth of snow or slush is of no operational significance, the letters XX is reported. This requires that the aircraft operators have given the aerodrome operator the necessary background for the use of XX.

H –Friction

The level of friction on a runway may be reported as measured or estimated. If the aerodrome operator not can answer for the friction level or the conditions exceeds those acceptable to the measuring devices, then the number 9 shall be reported.

Measured friction level may only be reported when the conditions are within those acceptable to the measuring device. Measured friction level is reported for each third of the runway as viewed from the threshold having the lower runway number and is reported in 2 digits (0 and point is omitted) followed by the sign for the friction measuring device. Ref. item 2.6 and 2.7 below for further information.

The friction may be estimated by a qualified person. Estimated friction level is reported for each third of the runway as viewed from the threshold having the lower runway number and is reported in 1 digit according to the following table:

5	Good	Friction level 0,40 and above
4	Medium/good	Friction level 0,36 –0,39
3	Medium	Friction level 0,30 –0,35
2	Medium/poor	Friction level 0,26 –0,29
1	Poor	Friction level 0,25 and below
9		Not to be estimated

1.7.10.5

2.6 Friction measuring devices and acceptable conditions

2.6.1 The following friction measuring devices are accepted for use at Norwegian aerodromes:

–GRT –Grip Tester

–SFH –Surface Friction Tester, High pressure tyre

–SKH –Skiddometer BV 11, High pressure tyre

–RUN –Runar

–VIN –Vertec Inspector

–TAP –Tapleymeter

2.6.2 In general there is great uncertainty related to measurement carried out under wet conditions. The snow and ice is then at its melting point. For instance is TAP not accepted under wet conditions. Ref. is made to item 2.7 below for more information.

2.6.3 A measured friction level is associated with the measuring device and can not be used as an isolated number. The acceptable conditions for the measuring devices are:

SKH/SFH:

–Dry snow up to 25 mm.

–Dry compact snow –any thickness

–Dry ice –any thickness

–Slush up to 3 mm.

–Wet snow up to 3 mm.

–Wet ice.

GRT/RUN/VIN:

–Dry snow up to 25 mm.

–Dry compact snow –any thickness

–Dry ice –any thickness

–Slush up to 3 mm.

–Wet snow up to 3 mm.

TAP:

-Dry snow up to 5 mm.

–Dry compact snow –any thickness.

–Dry ice –any thickness.

2.7 SNOWTAM format item H

The table used under item H, with associated descriptions, was developed in the early 1950's from friction data collected only on compact snow and ice. The friction levels should not be regarded as absolute values and they are generally not valid for other surfaces than compact snow or ice.

Nevertheless it is accepted that friction level may be reported when conditions with wet snow or slush up to 3 mm depth are present and a continuous measuring device is being used. A numerical expression regarding the quality of the friction levels reported in the SNOWTAM can not be provided. Tests show that the accuracy indicated in the table can not be provided using todays friction measuring devices. While the table use numbers with two digits, the tests show that only numbers with one digit can be of operational value. Utmost caution should therefore be taken when using the reported friction levels, and the use of the table must be based upon the aircraft operators own experience.

2.8 Distribution of SNOWTAM

The aerodrome services reports the status and significant changes of the conditions at the movement area to the ATS at the aerodrome. The ATS unit will in turn forward these reports as SNOWTAM through NAIS/AFTN to national and international addresses. At the same time the information is stored in the NAIS database. Latest updated information is then at any given time available for users connected to NAIS, or through internett to NAIS – IPPC (Internet Pilot Planning Centre).

Internationally SNOWTAM is distributed to AFTN collective addresses as stated by the appropriate administration/organisation in the receiving State. Intern distribution within each State is arranged by the appropriate administration/organisation. The distribution list is published every year in seasonal AIC. As the information at any given time is available from the NAIS database, the SNOWTAM's are given a limited direct distribution nationally. Under special written circumstances (special difficult conditions) an extended national distribution is used. Information regarding national distribution system is available at the Aeronautical Information Service Dep., NOTAM office and at any ATS unit in Norway. Inquiry regarding adjustment of national distribution can also be directed to these.

1.7.10.6 At the time of the incident there was in effect an Aeronautical Information Circular (AIC) issued by the Norwegian Civil Aviation Authority (CAA-N), that modified the reporting intervals to be 3 mm for slush, 6 mm for wet snow and 8 mm for dry snow. This means that 4 mm of slush would be reported as 6 mm of slush, 9 mm of wet snow would be reported as 12 mm and 10 mm of dry snow would be reported as 16 mm.

1.7.10.7 AIP Norway, section 2.7 SNOWTAM format item H is stating that the SNOWTAM table:

> *"was developed during the 1950's from friction data collected only from compact snow and ice. The friction values should not be regarded as absolute values and they are generally not valid for other surfaces than compact snow and ice."*

………………………………………………………………………………………………

"Tests show that the accuracy indicated in the table can not be provided using today's friction measuring devices. While the table uses numbers with two digits, the tests show that only numbers with one digit can be of operational value."

1.8 Aids to navigation

Not applicable.

1.9 Communications

ATC communication on TWR frequency 120.100 MHz was normal.

1.10 Aerodrome information

AIP NORGE/NORWAY AD 2 ENEV 2 - 1

AERODROME CHART	68°29'20''N 016°40'42''E WGS 84	AD ELEV 84 FT	TWR 120.100 MHz ATIS 126.025 MHz	HARSTAD/NARVIK EVENES NORWAY

RWY	BRG (GEO)	THRESHOLD		BEARING STRENGTH	DECLARED DISTANCES				TWY AND APRON
					TORA	ASDA	TODA	LDA	
17	177.60°	683011.10N	0164036.34E	PCN-65 F/A/W/U	2815	2815	3097	2723	TWY C, D 25 m WIDE, OTHERS 21 m.
35	357.60°	682845.40N	0164046.14E	PCN-65 F/A/W/U	2815	2815	3053	2750	

Figure 5. Aerodrome chart ENEV.

Harstad/Narvik airport Evenes (ENEV) has a 2,815 x 45 m asphalt runway designated RWY 17/35.

The take off threshold platform at the taxiway F intersection is made of concrete, while the runway and taxiways are made of asphalt. On the last 50 m of this platform Coefficient of Friction (CF) is not measured. This platform is usually more slippery close to the end due to less preparation because of turning restrictions of the sanding and measuring vehicles.

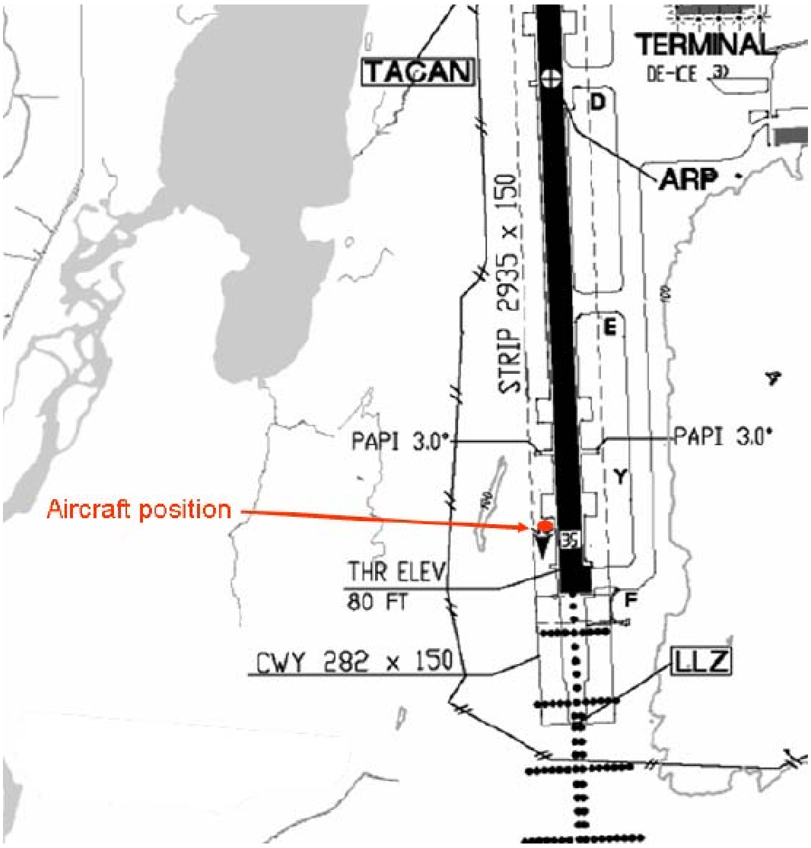

Figure 6. Runway 35 approach end.

1.11 Flight recorders

1.11.1 The aircraft was fitted with a Digital Flight Data Recorder (DFDR) and a solid state Cockpit Voice Recorder (CVR). The DFDR and CVR were recovered from the aircraft and sent to the UK Aircraft Accident Investigation Branch (AAIB) for analysis. The DFDR data were generally of good quality and correlated well with the crew's observations. The CVR data was of good quality and supported the crew's recollection of the event.

1.11.2 The data were sent to Rolls-Royce/IAE International Aero Engines AG (V2500 engine manufacturer) for further analysis. The report is from the V2500 engine specialist is shown in Appendix C.

1.11.3 From the DFDR data the following timeline summary show the significant parameters:

Time	Subframe No.	Event	Heading (deg)	Ground Speed (kts)	Comments
21:18:11	176015,0	No.2 Engine start	275,976	0	Starboard engine start sequence
21:18:55	176059,6	No.1 Engine start			Port engine start sequence
21:20:34	176159,4	Engine inlet cowl anti-ice on			
21:22:55	176294,6	Park Brake off			
21:22:55	176298,6	Taxi begins		15	Taxi speed varies between 4 to 15 kts

21:28:54	176657,0	Aircraft brought to halt, then No.1 engine throttle increased.	165,937	1	Temporary pause, No.1 engine throttle advanced. TLA 5.62 deg, Max EPR achieved 1.02734 and 69.75% N2, 406 deg EGT
21:28:59	176663,0	No.1 engine throttle pulled back		0	
21:29:30	176693,6	Park brake applied	168,398	0	Hold - reported due to pilot request to grit/ clear snow from runway/taxiway
21:34:49	177012,6	Park brake released			
21:34:58	177022,1	Turn commences			Turn on to runway
21:34:56	177019,0	No.1 engine throttle advanced to assist turn		1	TLA 5.62 deg, Max EPR 1.02343, 70.75%N2, 396 deg EGT
21:35:41	177064,1	Turn complete	354,726	0	Pedal brakes only applied
21:35:58	177081,8	Brakes off	355,078	0	
21:36:04	177087,6	Start of throttle advance		3	No.2 engine N2 speed 7% higher than No.1 prior to accel. EPRC = 1.34375, No.1 EPRmax=1.10547 No.2 EPRmax=1.34375[4] No.1 N2max=80.5% No.2 N2max=89.4%, No.1 EGTmax=445deg, No.2 EGTmax=464deg
21:36:12	177095,1	Heading deviation begins	351,914	4	Rudder pedal input has no effect
21:36:13	177096,0	Throttles retarded to idle	346,640	10	Rudder input increased. Aircraft continues to increase speed up to 22kts max.
21:36:18	177101,3	Brakes applied	320,976	22	Full L and R brake applied - no differential braking
21:36:24	177107,6	Aircraft comes to dead stop	312,890	0	
21:36:41	177124,6	Parking brake applied			
21:47:48	177791,1	No.2 engine shut down			
21:47:53	177797,6	No.1 engine shutdown			

1.11.4 From the DFDR data it can be seen:

At a ground speed of 3 kt the PF (First Officer) selected intermediate Throttle Lever Angle (TLA, throttle positions) of left 2.8° TLA and right 5.6° TLA. During this time period the No 1 TLA was leading the No 2 TLA by 2.8°. The 2.8°/5.6° throttle lever positions were held for 5.5 seconds. During this time period the EPR No 1 was stable at 1.014 while No 2 EPR increased steadily from 1.012 to 1.020, and thereafter continuously to its maximum of 1.336. Thereafter the TLAs were steadily increased to the FLEX take off TLA of 33.8°, held in this position 0.5 second and then pulled to idle. The EPR No 1 continued to rise to a maximum of 1.105 as the No 1 TLA reached 0°, while the EPR No 2 continued to rise to a maximum of 1.336 as the No 2 TLA reached 0°. At this time the ground speed had increased to its maximum of 22 kt, some 5 seconds after the TLA reached idle positions. The EPRs were not stabilised at 1.05 before throttle

[4] The slight difference between IAE numbers and AIBN numbers is due to AIBN is using a lower sampling rate

lever advancement for take off as recommended in the Flight Crew Operating Manual (FCOM). The whole event lasted 22 seconds from initial throttle lever advancement to the aircraft stopped off the runway. The crew forgot to perform the ice shedding procedure as prescribed in the MYT A320/1/330 FCOM, 3.03.09 P2 Oct 04 (Appendix I).

1.12 Aircraft and impact information

1.12.1 The damage to the aircraft was to non-structural items of the nose gear assembly. The left nose wheel tyre was punctured, the left nose wheel hubcap was deformed and one nose leg taxi light was broken.

Figure 7. Left punctured nose wheel with damaged hubcap.

1.12.2 The aircraft came to rest in the snow and soil on the left side of RWY 35, a position 125 m from the green threshold lights, with its nose 35 m from the runway hard surface edge and its tail 12 m from the runway edge. The aircraft's nose pointed approximately 40° offset from the runway centre line.

1.12.3 The nose wheels had ploughed an 8 m long furrow in the soft soil adjacent to the runway (Figure 4). The furrow was approximately 1 m wide and 60 cm deep. The right main wheels had sunk approximately 12 cm into the soil, while the left main wheels did not sink in. (Figures 2 and 3).

1.13 Medical and pathological information

The crews were not tested for drugs.

1.14 Fire

There was no fire.

1.15 Survival aspects

The passengers and crew evacuated normally through the rear cabin door and airport steps. They were brought to the airport terminal in buses. No injuries were registered. Fire trucks where standing by near the aircraft.

1.16 Tests and research

Not applicable.

1.17 Organizational and management information

1.17.1 MyTravel Airways Ltd (UK) is a charter company operating out of Manchester, UK. The airline began operations in March 1991. The main operating base is at Manchester airport UK, in addition the airline has operating bases located at Belfast, Birmingham, Bristol (Summer only), Cardiff (Summer only), Nottingham East Midlands, London Gatwick, Glasgow and Newcastle.

1.17.2 At the time of the incident the airline was performing international and domestic charter flights, passenger and cargo service to 36 cities in 24 countries. At the time of the incident the company operated a fleet of 21 Airbus 320/321/330, 3 Boeing 767, 4 Boeing 757 and 1 DC-10 aircraft.

1.17.3 As of November 2004, MyTravel Airways Ltd (UK) employed approximately 1600 employees, consisting of 415 pilots, 710 flight attendants, 24 maintenance and engineering staff, 11 general administration staff, 35 regional station staff, and 190 staff engaged in miscellaneous airline functions.

1.17.4 MyTravel Airways Ltd (UK)'s Executive and Senior Management staff is centrally located within the airline's main offices in Manchester, UK. The airline's Managing Director (Accountable Manager) is directly supported by the Director of Flight Operations, Engineering Director, Customer Service Director, Finance Director, Commercial Director, Head of Human Resources, Head of Flight Safety and Head of Security, Quality & External Affairs.

1.17.5 The Director of Flight Operations is supported by the Chief Pilot. The Chief Pilot is supported by his Flight Operations Management Team, structured as follows:

Training Manager is responsible for all fleet training issues with both the Safety Training Manager and Human Factors Training Manager reporting directly to the Training Manager. Training Manager reports to the Chief Pilot.

1.17.6 Fleet Managers for both North (MAN, GLA, BFS bases) and South (BHX, LGW, EMA, CWL, BRS bases) regions report to the Chief Pilot.

1.17.7 Reporting directly to Fleet Managers are the Fleet Operations Managers (FOM) posted as follows: FOM North, FOM South, FOM MAN, FOM LGW.

1.17.8 Base Pilot Managers report directly to the appropriate Fleet Operations Managers and are the first point of contact for all management issues at base level. Line Pilots will report to their Base Pilot Manager.

1.18 Additional information

1.18.1 Airbus/Company procedures

1.18.1.1 FCOM take off procedure is shown in Appendix 4. The procedure specify the thrust levers to be adjusted in two steps with a pause at 50% N1 or 1.05 EPR.

1.18.1.2 FCOM crosswind limits are shown in Appendix E.

1.18.1.3 FCOM contaminated runway definitions are shown in Appendix F.

1.18.1.4 FCOM contaminated runway operational conditions is shown in Appendix G.

1.18.1.5 MyTravel UK Operations Manual braking action information is shown in Appendix H-1 and H-2.

1.18.1.6 FCOM engine anti ice procedures are shown in Appendix I.

1.18.2 ICAO Doc 9137 AN/898 Airport Services Manual Part 2 Pavement Surface Conditions, Fourth Edition 2002

1.18.2.1 ICAO Doc 9137 contains internationally agreed recommended procedures for treatment of pavement surface conditions, including contaminations as slush, wet and dry snow, compact snow and ice.

1.18.2.2 Included in the document is a SNOWTAM table for Coefficients of Friction (CF) measured by, and valid for, all types of friction measuring equipment. This table contains friction numbers with two decimal digits with no measuring tolerances/uncertainties.

1.18.2.3 AIBN has documented information that the measuring uncertainty of the different friction measuring equipment listed in the ICAO Doc. 9137 is of the order of ± 0.10.

1.18.3 JAR-OPS requirement for correlation between friction measurement and ABC[5]

JAR-OPS 1.485(b), IEM OPS 1.485(b) Wet and Contaminated Runway data specify:

> *"If the performance data has been determined on the basis of measured runway friction coefficient, the operator should use a procedure correlating the measured runway friction coefficient and the effective braking coefficient of friction of the aeroplane type over the required speed range for the existing runway conditions."*

1.18.4 CAA UK's policy for operations on snow and ice contaminated runways

CAA UK does not permit operations on snow- and ice-covered runways in UK.

1.18.5 Airbus Industrie's recommended practice for cold weather operations

Airbus Industrie's policy on cold weather operations is described in a document named Getting to Grips with Cold Weather Operations[6]. An extract of the document is shown in Appendix J.

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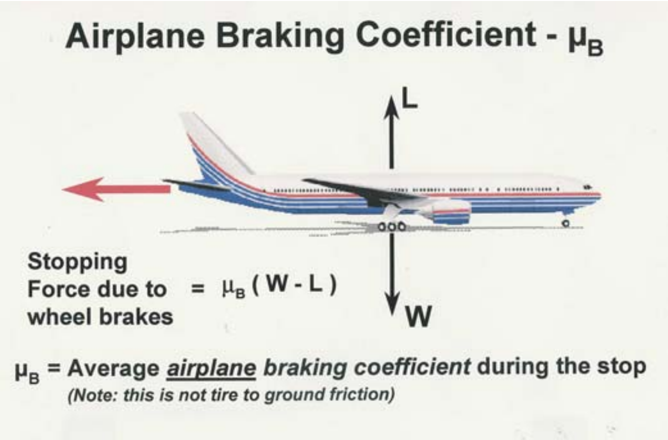
[5] Airplane Braking Coefficient in Boeing terms and Aircraft Effective μ in Airbus terms

1.18.6 BAE Systems Regional Aircraft

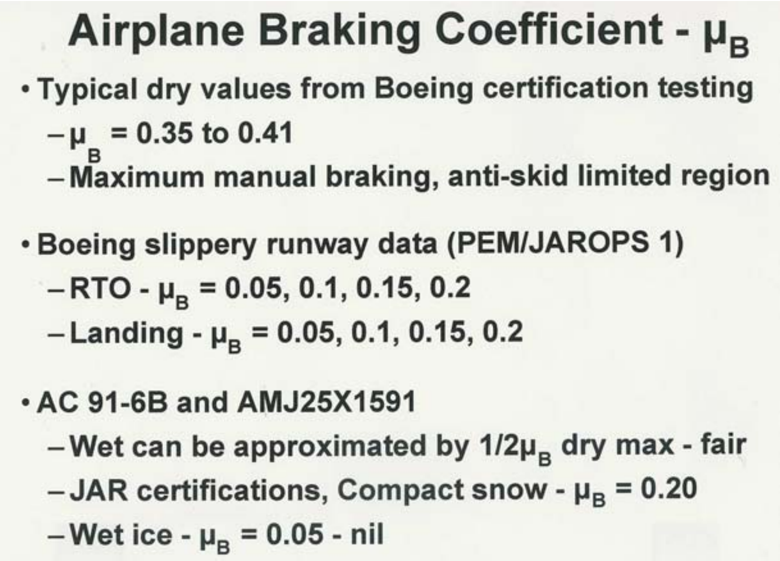
AIBN has extracted some of BAE Systems' views on icing certification[7]. This is shown in Appendix K.

1.18.7 Boeing aircraft

1.18.7.1 Boeing definition of Airplane Braking Coefficient (ABC).

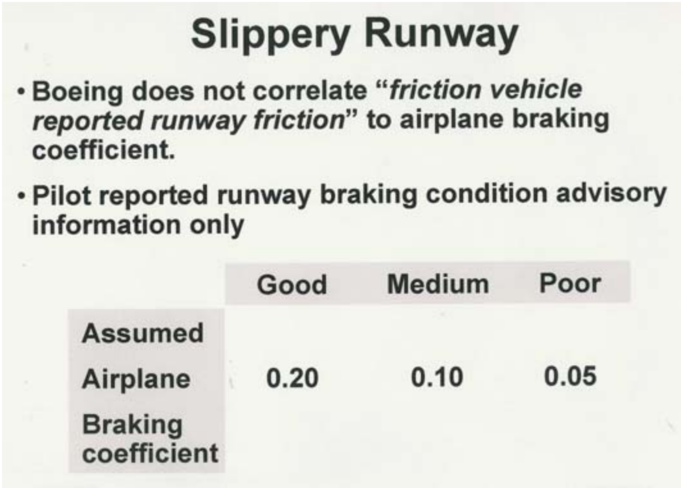


1.18.7.2 Boeing slippery runway data.



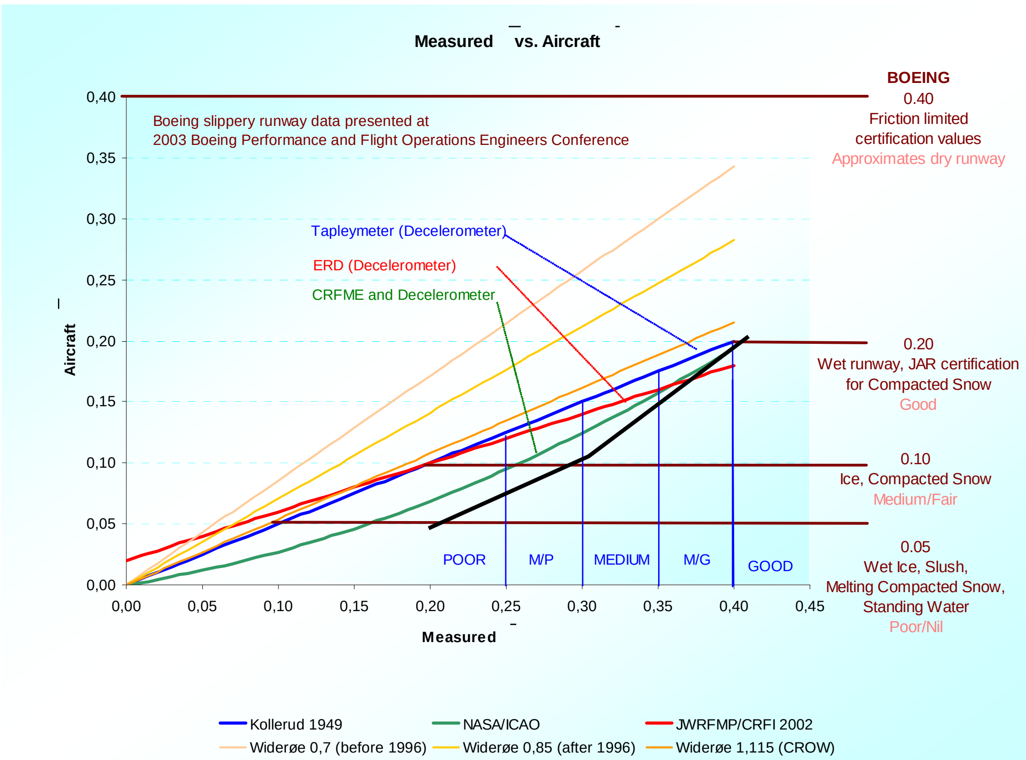
[6] Doc *AI/ST-F 945.9843/99*, AIRBUS INDUSTRIE Flight Operations Support Customer Services Directorate, 1999

[7] BAE Systems presentation at ERA Icing Workshop 21 November 2002



Airplane Braking Coefficient	Pilot Reported Braking Action	Runway Description
0.4	Approximates dry runway	Friction limited certification values
0.2	Good	Wet Runway, Jar certification for compact snow
0.1	Medium/Fair	Ice, Compacted Snow
0.05	Poor/Nil	Wet Ice, Slush, Melting Compacted Snow, Standing Water

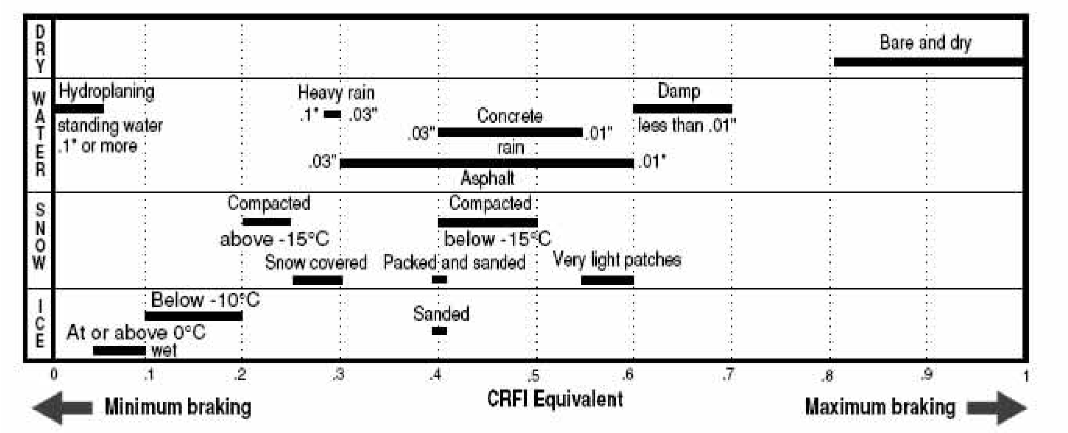
1.18.8 AIBN's summary of different correlation curves of CF vs ABC.



1.18.9 Friction measurement uncertainties.

YEAR	Organisation	Uncertainty	Remark
1962	ICAO	± 0.01	Reported by a State
1974	ICAO	± 0.15 - 0.20	Wet surfaces
1974	ICAO	± 0.10 - 0.15	Compacted snow and ice surfaces
1990	NASA	± 0.10	Contaminated
2005	ASTM	± 0.20 → ± 0.05	Use of ASTM standard E2100-04

1.18.10 Transport Canada's summary of contamination types versus CRFI[8]



1.18.11 Previous accidents and incidents reported to AIBN

1.18.11.1 During the last 8 years AIBN has received 24 reports on accidents and incidents related to slippery runways, measuring and reporting of Coefficients of Friction (CF). Based on this AIBN has launched a special investigation into "Winter Operations and Friction Measurements". This investigation is ongoing, but several of the findings are reflected in this report on the G-CRPH incident at ENEV.

1.18.11.2 Preliminary findings from the special investigation include, but are not limited to:

- The information in ICAO Doc. 9137, AN/898 Airport Services Manual, Part 2 Pavement Surface Conditions, Fourth Edition, 2002 is outdated, including:
- The correlation chart/table for friction measuring devices on compact snow- and/or ice-covered surfaces is not substantiated. Practical experience in Norway does not support the ICAO correlation values between different friction measuring devices on snow and ice contaminated runways.

[8] Canadian Runway Friction Index as defined by Transport Canada is equivalent to measured coefficient of friction

- The SNOWTAM table lists CF with two decimal digits and does not specify any measuring tolerances. Document research indicates that the tolerance or uncertainty is **± 0.10**. Hence the table should only list numbers with one decimal digit.

- The SNOWTAM table was developed during the 1950s and is based on tests on dry compact snow and dry ice using a decelerometer. These tests indicated that the correlation between measured CF and Airplane Braking Coefficient (ABC) was unreliable on wet surfaces. AIBN investigations show that all measuring devices are unreliable on wet snow and ice covered surfaces.

- The NASA developed and empirically established formula for the effective airplane braking coefficient $\mu\ eff = 0.2\mu + 0.7\mu\ max^2$ may be correct for wet runways but is not validated on snow- and ice-covered runways. Early tests in Norway during the late 1940s indicated an effective ABC of **0.5μ**, while later tests performed as part of the Joint Winter Runway Friction Measuring Program (JWRFMP) in Canada resulted in an effective ABC of **0.02 + 0.4μ** (Reference 6).

1.18.11.3 Based on preliminary findings during these investigations, AIBN considers it urgent to revise the Norwegian regulations and practices related to winter operations and has issued the following safety recommendations to CAA-N:

- *"AIP Norway and BSL E include Norwegian regulations regarding friction measuring equipment and measurement areas. AIBN has determined that the actual friction numbers often deviate from measured/reported numbers. Experience has shown that none of the approved friction measuring devices is reliable during damp/wet conditions, including temperature conditions with a difference of 3°C or less between air temperature and dew point temperature. AIBN is therefore of the opinion that reported friction during damp/wet conditions should be reported as POOR. AIBN recommends that the Civil Aviation Authority considers altering the measurement areas for the approved friction measuring devices in AIP Norway and BSL E. (Immediate safety recommendation SL 06/1350-1).*

- *The investigations of AIBN show that the various airlines use different correlation curves/tables. Investigations show that several of these correlation curves are based on uncertain foundations and they provide very inaccurate/unreliable braking values for the relevant aircraft types. The ICAO SNOWTAM table for measured friction numbers is based on measured numbers in hundredths and depends on the type of friction measuring device that has been used. AIBN investigations show that the various friction measuring devices provide different numbers on the same surface. AIP Norway describes the use of friction measuring equipment in general and warns against such large uncertainties in measurements that the accuracy of reporting should not be higher than tenths. Based on these circumstances, AIBN recommends that the Civil Aviation Authority considers simplifying the SNOWTAM table by eliminating the intermediate levels so that one is left with the areas Good, Medium and Poor, as well as removing hundredths and excluding the use of interpolation between the areas. (Immediate safety recommendation SL 06/1350-2).*

- *AIBN investigations show that performance data for landing on slippery runways using engine thrust (reversing) has been published for newer aircraft types (e.g. Airbus and newer Boeing aircraft). Such data has not been published for older aircraft types. The investigations further show that the effect of reversing engines is* *limited to approximately 25% of all available braking force and that this braking force should constitute a backup when landing on slippery runways. AIBN recommends that the Civil Aviation Authority should consider not allowing the inclusion of engine reversing in the calculated relevant (within 30 min prior to landing) stopping distance on slippery runways. (Immediate safety recommendation SL 06/1350-3).*

- *AIBN investigations show that the airlines' side wind limitations in combination with slippery runways are far too optimistic. The investigations have also confirmed that for certain aircraft types, these tables do not derive from the manufacturer of the aircraft, but have been prepared by individual airlines based on experience. None of the side wind tables have been approved by the authorities. Transport Canada has published one such table of side wind versus friction numbers. This is far more conservative than the tables used by Norwegian airlines. AIBN recommends that the Civil Aviation Authority assesses the airlines' side wind limitations in relation to friction coefficients/braking action, and also considers whether these should be approved by the authorities. (Immediate safety recommendation SL 06/1350-4)."*

1.19 Useful or effective investigation techniques

In this investigation no methods have been used which qualify for any specific description.

2. ANALYSIS

2.1 General

2.1.1 AIBN considers any runway excursion as a serious incident[9]. The main reason for this classification is the possible structural damage which may cause a possible fuel leakage and fire.

2.1.2 The analysis is based on reports and interviews with the Commander and First Officer, reports from the Air Traffic Controller and airport personnel, and interviews with MyTravel UK operational and management personnel. Further, AIBN has analysed CVR and DFDR data, as well as ATC communication recordings. There is no conflicting information from these sources. In order to identify the weak safety barriers, AIBN considers it important to analyse the event and the crew's actions in the context of the circumstances.

2.1.3 Further, AIBN is basing the analysis on information from several aircraft manufacturers regarding their views on operations on contaminated and slippery runways. Based on AIBN's investigations of several runway excursion accidents and incidents over several years, it is AIBN's view that the international knowledge and guidelines regarding operations on contaminated and slippery runways are lacking the necessary scientific foundation. Hence, there is a continuous demand for further research and development regarding operations on winter contaminated runways, and correlating types of contamination with airplane braking coefficients (ABC, or airplane effective µ).

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[9] Based on ICAO Annex 13 and Norwegian regulations

2.2 Air crew procedures

2.2.1 Civil Aviation Association (CAA) does not permit operations on winter contaminated/slippery runways in UK. British aircrews are therefore not regularly operating under such conditions. Further, the Airbus Industrie based company operating procedures are based on the concept of "fluid contaminated runway". AIBN considers this concept to be very uncertain and based on insufficient scientific documentation. Further, this and one other runway excursion incident with an Airbus airplane in Norway recently, indicate that the Airbus' procedures are difficult to relate to Norwegian winter operations.

2.2.2 The ATIS information received by the crew supported the TAFs and METARs regarding snowing conditions. Hence, the crew understood that the runway and taxiways were covered by snow. However, they had no information (SNOWTAM) available regarding the underlying ice and compact snow under the top layer of fresh snow.

2.2.3 Based on the weather and runway information they had available, the crew selected the "wet runway" take off calculation. This was based on the presumption that the runway was covered by less than 15 mm of dry snow. Since the reported snow depth was 8 mm of dry snow, this was seemingly acceptable. However, the crew did not at that time take into account that the runway was covered by sanded ice below the reported dry snow. AIBN considers this mistake to be a result of the Airbus Industrie's winter operation procedures which does not address such combinations of contaminations.

2.2.4 The crew then performed the take off calculation in accordance with the company procedures which are based on the Airbus FCOM. According to the Airbus FCOM, less than 15 mm dry snow is equivalent to a wet runway and the take off performance is calculated for a "fluid contaminated runway" (Appendix F). Based on this information the crew calculated the performance data for a wet runway. Further, the FCOM requires the minimum braking action for take off on the Airbus fleet to be MEDIUM in all three sectors of the runway (Appendix D). Based on this information the crew requested to the ATC that the runway braking action should be improved by more sanding and that they required a minimum braking action of MEDIUM. Apparently they misinterpreted the company correlation table between different measurement types that they needed a minimum of 29 to be MEDIUM, while the table specify CF of 0.36-0.42 measured with SKH/BV-11 in the MEDIUM range (Appendix H-2). ICAO Doc. 9137[10] has a correlation figure describing the differences between different friction measurement devices. AIBN's experience is that the values in the table are not correct and that it is not sufficient scientific evidence behind the correlation table. Further, the ICAO table gives the impression that the different measuring devices can measure the runway CF to an accuracy of ± 0.01 Even an accuracy of ± 0.10 is questionable under some conditions. AIBN's investigations show that the uncertainties for all types of friction measurement devices are in the order of ±0.10 (conf. item 1.18.9). Hence, all friction measurement devices should be treated equally, and MyTravel's company table in Operations Manual Part A 8.2.4.12 Braking Action should be deleted (Appendix H-2).

2.2.5 Since the flight crew was not aware of the effect of the sanded ice underneath the snow they did not consider the runway to be contaminated. Hence, they based their take off performance on an equivalent "wet" runway ("fluid contaminated runway") and selected a FLEX take off procedure. For a "contaminated" runway (ice or compact snow) the

[10] ICAO Doc 9137 AN/898, Airport Services Manual Part 2, Pavement Surfaces Conditions, Fourth Edition 2002

FCOM requires maximum thrust for take off (Appendix G). The use of the FLEX take off procedure did not have any adverse effect on the outcome, but in this case probably made the asymmetric thrust somewhat less.

2.2.6 The taxiing to de-icing and to the takeoff runway was performed without problems. The crew was continuously kept updated on the runway status and braking action by the ATC. The friction numbers were above 30 (MEDIUM) and acceptable to the crew. During the back-tracking for take off on runway 35, the crew was informed by the ATC that the runway was very slippery in the far south end. The crew did not fully realize the implications of this message and wanted to use the full length of runway 35 for take off. This is understandable as they had planned for a “fluid contaminated runway” with less than maximum take off thrust. During the back-tracking for take off, the PF taxied normally at a maximum ground speed of 15 kt. He did not experience any difficulties when braking in order to reduce the speed before starting the turn. The First Officer felt that the braking action was as reported. However, when the he tried to turn the aircraft to the right in the far south end, south of the runway at taxiway F, the nose wheel lost grip and skidded straight ahead. This may have been seen as a warning to the crew that the runway was indeed very slippery in the south end, and that they should exercise extra caution. Apparently, the full significance of the warning was not understood by the crew. This may be the result of the crew’s inexperience of operating on Norwegian contaminated runways, where quite often the runways are covered with different layers of contamination. In this case the runway was covered with snow on top of sanded ice. At this stage the crew had already satisfied themselves with the wrong understanding that the runway was covered with 6-8 mm of dry snow. Hence, they planned on a “fluid contaminated runway” according to the Airbus/company procedures.

2.2.7 The Commander took control of the aircraft and after extra sanding in front of the aircraft, he managed to complete the turn into take off position runway 35. He continued a few metres straight ahead to a portion of the runway, which to him looked less contaminated as he could see the runway markings beneath the snow. He then braked to a full stop and handed the control back to the First Officer. Here, an important item was forgotten by the crew. The FCOM after start procedure calls for engine anti-ice before take off if conditions warrant. The meteorological conditions at the time of starting and taxiing as defined in the FCOM, dictated use of the engine anti-ice procedure (Appendix I). This includes engine run-ups to 50 % N1 (EPR 1.05) at intervals not greater than 15 minutes. Subsequent take off under such conditions should be proceeded by a static run-up to as high a thrust as practical (50 % N1 recommended) with observation of all primary parameters to ensure normal engine operation. However, the FCOM does not specify how to perform the static engine run-up on slippery runways with poor braking action.

2.2.8 During the 6 min stop while waiting for extra sanding in front of the aircraft, ice was probably forming on the No. 1 engine Low Pressure Compressor (LPC) blades, the LPC guide vanes and the Fan Exit Guide Vanes (FEGV). It is considered that due to the prolonged taxi phase, the 6 min hold with the No. 2 engine shielded from the prevailing wind by the fuselage, and the No. 1 engine slightly off idle to assist the turn on to the runway, caused ice to build up (ref. item 1.11.2). It is believed that the ice in the No. 1 engine led to restricted air flow within the compressor causing asymmetric thrust.

2.2.9 The First Officer was in control and initiated the take off procedure. He increased the thrust levers and paused at an intermediate setting. The FCOM normal take off procedure calls for a stabilization of thrust at 1.05 Engine Pressure Ratio (EPR) which is about 50 %

N1 (Appendix D). In his recollection the First Officer maintained that he did pause at an intermediate thrust lever setting. However, the DFDR data show that the EPR No. 1 was stabilised at 1.014 (conf. item 1.11.4) while the EPR No. 2 never stabilised but increased steadily up to a maximum of 1.336, and the EPR No. 1 reached a maximum of 1.105. Further, the DFDR data showed that the No. 2 thrust lever was leading the No. 1. Hence, the No. 2 engine was producing an increasing asymmetric directional moment to the left which the pilots were unable to control.

2.2.10 The First Officer noticed the left swing of the aircraft immediately as the aircraft started to accelerate, and pulled the thrust levers to idle. Due to the engine inertia the engine rpm and EPR continued to increase and the asymmetric moment continued to build up even with the thrust levers at idle at a ground speed of 10 kt. The First Officer tried to steer back towards the centreline by application of full rudder input to the right. As he felt no response from the pedal input he even tried the hand tiller to regain directional control with the nose wheel steering, but with no success. The surface friction was too low for the nose wheel to take steering (low cornering friction), and with the aircraft moving to the side of the runway he applied the brakes, to no effect. The runway surface was so slippery that neither the nose wheel steering input at low steering angles, nor the brakes were effective. Under similar circumstances with MEDIUM braking action it would normally be possible to arrest any deviation from heading and keep the aircraft on the runway.

2.2.11 The maximum nose wheel steering angle on this type of aircraft is 6° by use of the rudder. According to ICAO Doc. 9137 a steering angle of 6° requires a typical side friction coefficient of 0.1. As the aircraft did not respond to rudder steering, AIBN considers the runway CF to be less than 0.1 at the runway 35 threshold. Hence, the crew's use of the hand tiller only contributed to deflecting the nose wheel to its full deflection causing the nose wheel to skid sideways in the direction of movement. However, the fully deflected nose wheel caused increased braking due to the ploughing effect through the snow and soil (see Figure 2 and item 1.12.2).

2.2.12 British aviation regulations do not allow operations on contaminated/slippery runways. British airport runways are cleared of snow and ice before airplane operations are allowed. British crews flying in to Scandinavia therefore need special training before flying to winter contaminated airports. The crew had been trained for winter operations according to MyTravel Airways (UK) requirements and was qualified to operate on contaminated/slippery runways. The investigation show that the crew was not fully aware of the Norwegian concept of preparation of winter contaminated runways. AIBN is recommending that MyTravel Airways should revise its procedures and training requirements for operating on Norwegian winter contaminated/slippery runways.

2.3 Evacuation

2.3.1 When the aircraft had departed the runway and stopped, the First Officer prompted the Commander to make a "Cabin crew on stations" call to the cabin crew. The Commander however, felt that a "Passengers and crew remain seated" call was more appropriate and this was done. The passengers remained calmly in their seats and waited for further information. The Commander kept the passengers updated as the situation unfolded. AIBN considers the Commander's actions as reasonable under the circumstances.

2.3.2 The Commander's initial assessment of the situation was that the aircraft was just on the shoulder of the runway and that they could possibly be pulled back onto the runway. He soon realised that this was not possible and decided to shut down the engines and evacuate the passengers and crew.

2.3.3 The aircraft was evacuated through the aft cabin door and airport steps. The passengers were taken to the airport terminal building by bus and were not exposed to the cold conditions for any period long enough likely to cause injury.

2.4 Airbus Industrie's policy and procedures

2.4.1 The Airbus FCOM is based on Airbus' policy regarding contaminated runways (Appendix J). The main Airbus message is:

> *"…pilots cannot get the performance from reported μ or Braking Action. Pilots need the type and depth of contaminant on the runway…"*

The main Airbus objections to basing take off and landing performance on measured CF are the uncertainties of

> *"…the correlation between test devices, even though some correlation charts have been established"* and *"the correlation between measurements made with test devices or friction measuring vehicles and aircraft performance…"*

2.4.2 AIBN agrees with Airbus that there is an uncertainty regarding the correlation between measured CF and ABC (effective aircraft μ). AIBN has collected documentation from various sources which indicate that the correlation is reasonable reliable if one allows for the measuring uncertainty of ± 0.10 for all types of friction measuring equipment.

2.4.3 AIBN does not agree with Airbus policy of converting slush, wet and dry snow into the equivalence of water. AIBN has investigated several runway excursions which indicate that the actual CF for these types of contamination (Airbus' "fluid type of contamination"), may be much lower than for the equivalent water depth. In AIBN's view the uncertainty of basing the friction estimate on "fluid contamination's equivalence to water" is less certain than basing the estimate on measured CF and allowing for the measuring tolerance of ± 0.10.

2.4.4 The Airbus policy of converting slush, wet and dry snow to the equivalence of a wet runway, is considered by AIBN to be more uncertain than relying on a correlation curve between measured CF and ABC (conf. items 1.18.7-1.18.8 and reference 5). However, AIBN recommends that it should be agreed on possibly one correlation table for jet airplanes and one table for propeller airplanes.

2.4.5 AIBN has learned from several runway excursion accidents and incidents that runways covered with a certain contamination have been much more slippery than the type and depth of the contamination would suggest. Further, Airbus assumes that certain amounts of slush, wet and dry snow provide a certain ABC, equivalent to the value on a wet runway. Until recently the ABC value for a wet runway (0.20, GOOD) was estimated to be of the order of half the value for a dry runway (0.40, DRY), and similarly the ABC value for a slush-covered runway (0.10, MEDIUM) was estimated to be of the order of a quarter of the dry runway value. According to TC[11] the friction numbers vary a great deal within the same type of contamination (conf. item 1.18.10).

2.4.6 Further, Airbus uses fixed ABCs for compacted snow (0.20) and for ice (0.05). These are internationally agreed ABCs for braking action GOOD and POOR, and are used by Airbus, Boeing and other manufacturers (conf. items 1.18.5 - 1.18.7). These numbers are often referred to without specifying that these numbers are ABC or Aircraft Effective μ, and not runway CF. An example of this may be seen in Appendix J and K. This may lead to misunderstanding by users. It is important to keep in mind that these values are accepted default values for the aircraft effective μ (ABC) which the manufacturers may use when computing the stopping distances on contaminated and slippery runways.

2.4.7 Further complicating the issue, Airbus does not address the type of contamination consisting of sanded compact snow or ice, covered by slush, wet or dry snow. AIBN has not seen test results involving this type of contamination on runways. Information from TC provides an indication of the friction level on sanded compact snow or ice, but Norwegian experience shows that it may become very slippery with slush, wet or dry snow on top. The same thing has been seen when the air is moist, even at freezing temperatures.

2.4.8 AIBN believes that there is a contradiction in the Airbus FCOM. On the one hand the friction levels (or Braking Action) on slush, wet or dry snow are not provided (as MEDIUM or POOR). On the other hand the FCOM requires braking action MEDIUM on all three sectors of the runway for take off. Another confusing issue is the distinction between “fluid contaminated runway and “contaminated runway”. The first allows use of FLEX take off thrust while the latter requires MAX take off thrust. AIBN’s experience is that both types of contamination may be very slippery.

2.4.9 AIBN has compared different manufacturer’s procedures for operations on contaminated and slippery runways. Boeing has defined specific ABCs as 0.40 for “dry” runway, 0.20 for “wet”, 0.20 for GOOD, 0.10 for MEDIUM and 0.05 for POOR (The last three ABC’s are related to “contaminated/slippery runway”, conf. item 1.18.7). Boeing does not, however, support the policy of correlating ABC with measured friction numbers, but relates the ABC to Pilot Reported Runway Braking Condition (Braking Action) of GOOD, MEDIUM and POOR. The Boeing AFM slippery runway performance data are based on these values. A Norwegian B737 operator has received CAA-N approval for a correlation curve (conf. item 1.18.8, black thick line) correlating measured CF to ABC according to JAR OPS (conf. item 1.18.3).

2.4.10 AIBN is presently investigating two runway excursions involving Airbus 320/321 aircraft. Based on the AIBN investigations, information from other manufacturers and Norwegian experience, AIBN considers Airbus FCOM procedures related to operations on contaminated/slippery runways to be unclear, inaccurate and difficult for flight crew to adhere to. Further, AIBN considers the practice of converting slush, wet and dry snow to water as a very uncertain procedure without substantiated micrometeorological research. It is AIBN’s impression that the JAR certification basis for this method is primarily developed to cover the rejected take off case, balancing the take off performance against an aborted take off and braking. However, it is AIBN’s view that these Default Friction Values should only be used for take off calculations and not for landing calculations.

[11] Transport Canada, the Canadian civil aviation authority

2.4.11 Based on the investigations of several runway excursion incidents in Norway over the last few years, AIBN regards the ICAO SNOWTAM table to be misleading. With a documented uncertainty of ± 0.10, the table should be limited to GOOD (0.40), MEDIUM (0.30) and POOR (0.20). This is in line with Boeing's slippery runway data (conf. item 1.18.7).

2.4.12 Based on the investigations regarding several runway excursions on contaminated/slippery runways, AIBN considers the Airbus "Fluid contaminated runway" concept to be misleading and highly uncertain. AIBN advises Airbus to follow Boeings policy of relating specific Airplane Braking Coefficients (Airbus "effective μ) to Dry runway landing (0.40), Wet runway landing (0.20), Contaminated runway landing GOOD (0.20), Contaminated runway landing MEDIUM (0.10) and Contaminated runway landing POOR (0.05). These are also the international ICAO terms of slipperiness which all pilots, ATC and airport personnel are familiar with.

2.5 Norwegian regulations governing winter maintenance of runways

2.5.1 Norwegian regulations are based on ICAO Doc. 9137 (conf. item 1.7.10 and Reference 2). However, Norwegian experience from many years of winter operations has demonstrated the deficiency of these recommendations and procedures. This is reflected in the AIP Norway item 2.7 SNOWTAM item H caution (Reference 3):

> *"…while the table show numbers with two digits; tests show that only numbers with one digit may be of operational use".*

Based on the above, AIBN has recommended to CAA-N to initiate revision of the AIP Norway (conf. 1.18.11.3).

2.5.2 It is common practice at Norwegian airports to sand on top of compact snow and ice. However, experience has repeatedly shown that sand in loose contamination like slush, wet or dry snow will not adhere to the underneath surface. The sand particles will float in the loose contaminant and be deflected by the aircraft tires, or be blown away by wind, jet blast or wing wake turbulence. AIBN advises Avinor[12] to review this gritting method.

2.5.3 According to ICAO and JAR OPS recommendations, the first option for the airport management is to clear the runways free of snow and ice. It is only when this is not possible that operations on winter contaminated runways should be accepted.

2.5.4 Even though most aircraft manufacturers do not accept any correlation curve between measured CF and ABC, it is common international practice to base runway friction on friction measurements. As shown in item 1.18.3, JAR OPS requires operators who base their performance calculation on measured CF to use a correlation curve approved by the local authorities. ICAO Doc. 9137 contains one such correlation curve based on NASA studies. However, as shown in item 1.18.8, there are other curves available like the Kollerud and the Canadian curves. It is AIBN's recommendation to correlate ABC 0.20 to braking action GOOD, 0.10 to MEDIUM and 0.05 to POOR. This will take into account the uncertainty of the measured CF (with one decimal tolerance) and correlate with the ICAO recommended SNOWTAM braking action GOOD (0.40), MEDIUM (0.30) and POOR (0.20). This will reduce much of today's uncertainty when calculating an aircraft's

[12] Avinor is the Norwegian Air Traffic and Airport Management Organisation

breaking distance on a contaminated runway, and increase the safety margin during winter operations.

2.5.5 In Norway one Boeing 737 operator has been using a CAA-N approved correlation curve for several years with positive results. This curve is based on Boeing's ABC as referred to in item 1.18.7, correlating with the ICAO SNOWTAM table. AIBN considers the use of measured CF and a correlation table to give a larger safety margin than the Airbus procedures based on "Fluid Contamination" and "Equivalent of wet runway". Based on the above AIBN recommends that Airbus reviews the use of "Fluid Contaminated Runways" for landings.

2.5.6 AIBN's view is that the cause factors for the slippery south end of the runway were several:

- The runway was not sanded all the way to the end due to turning of the sanding vehicle. For the same reason the friction measurement was not performed quite to the end.
- The southern section (C-section) had not been sanded since 2030 hrs. After that time one jet aircraft (B737) took off and one propeller plane landed. AIBN considers it likely that the aircraft taking off and landing blew most of the sand off the runway.
- During the 6 min stop with a heading of 168° the engine exhaust gases were blowing onto the sanded centre portion of the runway and warming/melting some of the snow. This was also causing some of the sand to be blown off the runway.
- The wind direction was 359° resulting in the wind deflecting the exhaust further to the west. When the engine thrust on the left engine was increased to assist during the turn, the effect was increased.

2.6 AIBN investigation into Winter Operations and Friction Measurements.

2.6.1 During the last years AIBN has received several reports on accidents and incidents related to winter operations and friction measurements. AIBN considers this unacceptable and has launched a special investigation into these events (conf. item 1.18.11). The investigation into "Winter Operations and Friction Measurements" is ongoing, but several of the findings are reflected in this report on the G-CRPH incident at ENEV.

2.6.2 During the investigations into this and other accidents and incidents related to operations on winter contaminated runways, AIBN has identified several deficiencies in ICAO, AIP Norway and Airbus Industrie's documentation. AIBN may issue further recommendations when these investigations are completed.

3. CONCLUSIONS

3.1 Findings

a) The crew were properly certified and trained for the operation.

b) The aircraft was maintained in accordance with JAR 145 and was serviceable at the time of the incident.

c) The aircraft mass and balance were within limits.

d) The aircraft was loaded with 10,000 kg of JET A-1 fuel at the time of the incident.

e) The runway and taxiways were covered with sanded ice and compact snow with 6 mm dry snow on top. The braking action on the take off runway 35 was 30-32-32, measured by Skiddometer (BV-11).

f) The measured numbers satisfied the MyTravel Airways company regulations requiring braking action MEDIUM-MEDIUM-MEDIUM on all three sectors of the departure runway.

g) The crew did not receive or request the latest SNOWTAM for ENEV before departure.

h) The crew did not register that the runway was covered with ice beneath the dry snow. Hence, they based their take off performance on the Airbus FCOM "Fluid Contaminated Runway" and planned on using a FLEX take off procedure, while the Airbus FCOM calls for a maximum thrust take off on a runway contaminated by ice or compact snow.

i) The use of the FLEX take off procedure did not affect the outcome of the incident.

j) The crew was cautioned by the ATC controller that the south end of the runway was very slippery.

k) The crew experienced difficulties when trying to turn the aircraft to line up for take off. They held for 6 min while a gritting truck gritted in front of the aircraft. After gritting the crew successfully turned the aircraft into take off position.

l) The crew did not use the engine de-ice/ice shedding procedure during taxing and before run-up for take off.

m) The crew did not stabilize the engines at 1.05 EPR before selecting take off thrust.

n) The pilots were unable to control the aircraft on the slippery runway.

o) The passengers and crew were all unharmed and evacuated in an orderly way using the aft cabin door and airport steps. They were transported by bus back to the terminal building.

p) Airbus FCOM procedures for "Fluid Contaminated Runways" are misleading and difficult for pilots to adhere to.

q) MyTravel Airways UK's OM Part A 8.2.4.12 Braking Action correlation table for different friction measuring equipment is wrong. The table is not addressing the uncertainty of ± 0.10 for all types.

r) The CAA UK does not permit operations on winter contaminated/slippery runways. Hence, UK pilots lack knowledge and experience of operating on Scandinavian snow- and ice-covered runways. This results in limited pilot knowledge about Norwegian winter operations and procedures.

s) The ICAO Doc. 9137 SNOWTAM table of measured coefficients of friction includes friction numbers with two decimal digits in spite of the documented ± 0.10 uncertainty. In addition, some other information in the document is outdated.

t) AIP Norway information governing winter maintenance of runways is outdated

u) The Norwegian practice of sand gritting on loose slush, wet or dry snow on top of ice or compact snow does not provide the expected ABC. Similarly, the practice of measuring runway friction coefficient on wet conditions provides erroneous CF. Norwegian experience has shown many times that the measured CF does not correlate to usable ABC during these conditions.

v) It is common practice in Norway to base take off and landing performance on measured runway friction coefficients during contaminated/slippery conditions in line with ICAO and JAR OPS recommended procedures.

w) JAR OPS regulations require a procedure correlating the measured runway friction coefficient and the effective braking coefficient of friction of the aeroplane type if the performance has been determined on the basis of measured runway friction coefficients. Neither AIP Norway nor any other Norwegian regulations include a common CAA-N approved correlation curve or table.

x) AIBN has received 24 reports on accidents and incidents related to winter operations and runway friction measurements during the last 8 years. The investigations are ongoing and AIBN has issued 4 immediate safety recommendations in this regard to CAA-N.

3.2 Significant findings

a) Due to icing in the No. 1 engine resulting in asymmetric thrust, the aircraft veered to the left during engine acceleration.

b) Due to an extremely slippery runway, with a CF much lower than the measured and reported friction number of around 30 (MEDIUM), the actual runway friction was too low for nose wheel steering and for braking.

c) Airbus Industrie’s concept of basing aircraft take off and landing performance on “Fluid Contamination” and “Equivalent to Wet Runway” is misleading and not substantiated by scientific research. AIBN investigations and Norwegian experience show that “fluid contaminations” very often result in POOR braking action, contrary to the present belief of some organisations.

d) The Norwegian practice of measuring friction on compact snow or ice covered by loose dry snow, wet snow or slush may be outside the approved acceptable conditions for the measuring devices.

4. SAFETY RECOMMENDATIONS[13]

AIBN is working on an investigation regarding winter operations in general. This report is a part of that investigation, and further safety recommendations regarding winter operations and friction measurements may follow.

Safety recommendation SL nr. 2007/25T

The AIBN investigations show deficiencies in the MyTravel SOP regarding operations on contaminated runways. AIBN recommends that MyTravel Airways UK review their OM Part A related to these types of operations.

Safety recommendation SL nr. 2007/26T

The AIBN investigation shows that the pilots' understanding of different aspects of Norwegian winter operations is limited. AIBN recommends that MyTravel Airways UK review their training requirements for operations on contaminated runways in Norway.

Safety recommendation SL nr. 2007/27T

AIBN investigations show that Avinor's practice of measuring friction on compact snow or ice covered by loose dry snow, wet snow or slush may be outside the approved acceptable conditions for the measuring devices. AIBN recommends that Avinor review the acceptable conditions for the measuring devices.

Safety recommendation SL nr. 2007/28T

AIBN investigations show that the Airbus Industrie's concept of basing aircraft take off and landing performance on "Fluid Contamination" and "Equivalent to Wet Runway" is misleading and not substantiated by scientific research. AIBN investigations and Norwegian experience show that "fluid contaminations" very often result in POOR braking action, contrary to the present belief of some organisations. AIBN recommends that Airbus Industrie review their concept of "Fluid contamination being Equivalent to Wet Runway" for landing on contaminated runways.

Accident Investigation Board Norway

Lillestrøm, 7 August 2007

[13] The Ministry of Transport and Communications forwards safety recommendations to the Norwegian Civil Aviation Authority and/or other involved ministries for evaluation and monitoring, see Norwegian Regulations regarding public investigations of accidents and incidents in civil aviation, § 17.

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5. Contaminated and Slippery Runways, Boeing Company, Performance Engineer Operations, Flight Operations Engineering, 2001.

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APPENDIX

ABBREVIATIONS

ABC	Airplane Braking Coefficient
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
ASTM	American Standard of Measurements
ATC	Air Traffic Control
ATIS	Air Traffic Information Service
ATPL(A)	Air Transport Pilot’s Licence (Aeroplane)
BA	Braking Action
CAA-N	Civil Aviation Administration-Norway
CG	Centre of Gravity
CF	Coefficient of Friction
CRFI	Canadian Runway Friction Index
CRFME	Canadian Runway Friction Measurement Equipment
CRM	Crew Recourses Management
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
ENEV	Harstad/Narvik airport Evenes
EPR	Engine Pressure Ratio
ERD	Electronic Recording Decelerometer
FAR	Federal Aviation Regulations
FCOM	Flight Crew Operating Manual
FEGV	Fan Exit Guide Vanes
FH	Flight Hour
FLEX	Flexible take off power

IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
JAA	Joint Aviation Administrations
JAR	Joint Aviation Requirements
LPC	Low Pressure Compressor
MAC	Mean Aerodynamic Chord
METAR	Meteorological Aerodrome Report
MHz	Mega Hertz
MYT	MyTravel
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Air Men
N1	Fan RPM
N2	Core engine RPM
RWY	Runway
SKH	Skiddometer High pressure tire
S/N	Serial Number
SNOWTAM	Snow notice To Air Men
SOP	Standard Operating Procedure
TAF	Terminal Aerodrome Forecast
TC	Transport Canada
TLA	Throttle Lever Angle
TWR	Tower
UK	United Kingdom
UTC	Universal Time Coordinated
VNL	Corrective lenses
WIF	Widerøes Flyveselskap

APPENDIX B

Professor Reinhardt Mook (University of Tromsø, Norway) has analysed several runway excursions in Norway related to slippery runways. The following analysis is an extract from his report[14]:

The incident at Evenes on 25 November 2004 with MYT's A320, G-CRPH**.**

"...

Analysis

The pilot explained immediately following the incident that engine 1 lagged behind at start-up. If this is the case, the yawing moment caused the aircraft to deviate from the centreline. It should to a certain degree be possible to compensate for asymmetrical engine thrust by steering the aircraft given adequate shear force between the tyre and the runway. The pilot did not succeed in bringing the aircraft back to the centreline. Wind may be disregarded as a subsidiary cause. It is presumed that the difference in the performance of the engines has not been greater than should be expected and it is reasonable to conclude that the runway excursion was caused by the slippery runway. Whether the yawing moment was reinforced by lateral forces on wheels remains an open question. In the following it is presupposed that the used section of the runway (southern section) was more slippery that it should have been for the acceleration of the A320 with asymmetrical engine power.

There is no doubt that the runway surface was covered with ice. The ice had been sanded cold following the foregoing sweeping. According to witnesses, sand was blown away by the engines in a zone north of the position that the aircraft assumed while waiting for sanding in front of the nose wheel. Also, snow that must have covered the ice in this area would have been blown away as the aircraft passed or stopped. Traces of possible remaining snow, most probably the bare surface of the ice, could have melted at the surface due to hot engine fumes when the aircraft was motionless while waiting for sanding in front of the nose wheel. Additionally, it may be concluded from the air temperature that the surface temperature of the ice was well below freezing point.

Northwards the runway was contaminated by dry snow on ice. The regulations state that snow that is difficult to shape into a snowball is to be considered "dry". New dry snow will nevertheless contain liquid (supercooled) water that when subjected to pressure against a hard surface creates a film of liquid water.

It is assumed that the aircraft started to accelerate on the slick cement surface before passing a zone where sand and snow (for the most part) had been blown away and where melting due to hot fumes had occurred, but (after the aircraft had started to turn around) was in the process of freezing again. Further, the aircraft was to have entered a zone of new, dry snow on ice. The latter form of contamination was probably a given in the area where tracks indicated that the aircraft departed from the centreline. It is nevertheless possible that the origin of the runway excursion with regard to the grip of the runway is to be found closer to the starting position of the aircraft, where the speed of the aircraft was lower, cf. witness statements regarding unusual patterns of movement of the aircraft's lights. Which parts these zones of varying contamination may have played in

[14] Reinhard Mook, Micrometeorological processes on a runway contaminated by frozen water, 2006

relation to the development of the engines' asymmetrical thrust is difficult to assess without more substantial information.

With the exception of the area mentioned above, it can be assumed that the ice was covered with a film or layer of up to several millimetres of dry snow. Dry snow on dry ice creates an intermediate easily movable lubricant. The question of whether interaction with liquid water, vapour film lubrication or other processes were the decisive cause shall here give way to empirical experience regarding generally slippery conditions under the known circumstances.

It is known from experience that loose sand that is emulsified in snow or slush as a lubricant loses its purpose; sand "floats up" in the snow instead of sticking to the ice. The reported 6 millimetres of snow suggest a rich loose mass of at least 3 millimetres that would have degraded the intended effect of the cold loose sand.

It is common knowledge among pilots with experience from ENEV that new snow here often results in particularly slippery conditions. There are several possible reasons for this. Due to topography and the resulting vertical air currents it may be possible that the location is particularly exposed to such a composition of frozen precipitation (with enclosed liquid water) that special conditions arise. It could also be expected that salt from the sea could explain the phenomenon. However, without empirical investigation it is impossible to go beyond speculative hypotheses. These shall remain unconsidered here.

Conclusion

The runway excursion sideways (westward, to the left in the aircraft's direction of movement) requires a yawing moment greater than the transferable shear force to solid ground. The yawing moment is assumed to have been caused by asymmetrical engine thrust. If the grip had not been poor, the yawing moment created by the unequal engines may possibly have been compensated by shear force transferred by the steering nose wheel. The magnitude of yawing moment that during start-up may be transferred to solid ground decreases with the decreasing grip of the steering nose wheel. With increased (improved) grip, the potential for compensating for increased differences in engine thrust by steering with the nose wheel increases, all other conditions remaining the same. There is therefore reason to assume that a slippery surface has been a contributory or at least a promotive cause of the incident.

To begin with, the aircraft accelerated on ice where the sand had been blown off and where the ice presumably had a thin layer of water due to the heat of the engine fumes during a stop with the nose in the opposite direction of the take-off direction. While the aircraft turned, this layer would have been in the process of re-freezing. The properties of the ice surface (liquid during freezing) would have provided a very slippery surface.

If the aircraft departed from the centreline after approx. 50 m, it would already have been on ice contaminated by loose dry snow. It is well known that snow of this type can constitute a very effective lubricant: the mixture of crystal fragments, perhaps with a proportion of liquid water, is in itself a continuum that is barely able to transfer shear force. Further, the discontinuation between loose snow and dry ice constitutes a gliding surface. Sand mixed in the snow does not adhere to the static ice and thus does not promote grip. The intermediary mobile layer on ice was obviously not able to transfer the *lateral shear force unleashed by the nose wheel that could have brought the aircraft back to the centreline.*

The requirement of a B/A (SKH) of at least 29 for start with the A320 and the attempts to improve the measured B/A to barely above the marginal values, point to a physically unfounded confidence in or an inadequately critical attitude towards the measurement accuracy and reliability of BV11 (SKH) as well as the number scale's relevance for the accelerating aircraft's experienced friction. The pilot's understanding of the skiddometer's limitations and friction on bare ice seems to have been inadequate. It is also possible that airport personnel could have expressed a more critical attitude with regard to the measured B/A values towards the pilot.

The aircraft skidded with the nose wheel when turning at taxiing speed and required extra sanding in order to turn. This event should have been interpreted as a clear sign that the aircraft related conditions were worse than the measured B/A nominally would lead one to expect."

APPENDIX C

Report from the engine specialist:

"*I have studied the DFDR data as supplied by you via the AAIB. However, there is only limited engine data available and hence I can only draw a "most probable" conclusion from the data.*

The attached file is a timeline of the event.

(See attached file: G-CRPH timeline.xls) (Conf. item 1.11.3).

As there were few engine parameters on the DFDR and none relating to the N1 system it is difficult to interpret the actual circumstances surrounding the event, however, the following observations are thought relevant:

Both engines were started normally and stabilised. The idle N2 speeds were closely matched (within 1%) and the EGT was between 20 and 40 degrees higher on engine 2 than engine 1.
At 21:20:34 both engines' anti-ice was selected. When anti-ice is selected the engine is controlled to ensure that N1 speed does not drop below 18% N1 speed at idle.
Once the parking brake was released the aircraft began to move under idle thrust. There were fluctuations in both engines Throttle Lever Angle data of +/-2.8125 deg throughout the recording with no change in engine conditions. This is not considered to be a contributory factor to the event.
At 21:28:54 the aircraft was brought to a halt and then the No.1 engine throttle was advanced and a further taxi of 5 seconds was conducted at 1kt with the aircraft being brought to a halt again at 21:28:59.
At 21:29:30 the parking brake was applied and the aircraft was held stationary on a heading of 168.398 degrees with the engines at idle until 21:34:58. Met report confirms icing conditions and snow and ice was reported on the ground with wind coming from 359 deg. This hold was apparently to enable the runway or taxiway to be gritted or cleared of snow and was at the request of the flight crew. The runway was reported to IAE as being "ice covered".
At 21:34:58 the aircraft began to turn. At 21:34:56 the No.1 engine throttle was advanced slightly to assist the turn. The power setting was similar to that used for the short position adjustment in step 3. The rudder pedal remained neutral during the turn suggesting that the steering was conducted using the hand tiller.
At 21:35:41 the turn was completed and the aircraft was brought to a halt on the pedal brakes on a heading of 354.726 degrees.
The brakes were released at 21:35:58. The aircraft began to move forward and then at 21:36:04, the throttles were advanced progressively for take off to a TLA of 33.75 degrees. At no time were the throttles paused at part power to allow stabilisation, nor was any engine ice shedding procedure carried out (see additional notes below). Just prior to throttle advance, there was a step change in engine No.2 N2 of 7%. Whilst quite a small increase, the rotor inertia would be slightly higher and hence acceleration time would be

improved. However, during the throttle movement, the No.2 engine accelerated normally up to the commanded EPR, but the No.1 engine EPR only achieved a maximum of 1.10547 (against commanded EPR of 1.34375). The N2 increased, but remained 9% lower than the No.2 engine and while the EGT rose and maintained a 20 degree difference from the No.2 engine the fuel flow was only one third of the maximum fuel flow condition on the No.2 engine.
As the aircraft began to deviate from its heading both throttles were retarded to idle thrust at 21:36:13. The ground speed was only 10 kts at this point. Progressive rudder pedal input was fed to compensate the swing and it is assumed that as Antiskid was selected ON that the rudder pedal input would have been linked to Nosewheel steering (FCOM 1.32.30, P7). However, no effect is seen to counter the swing to the left with application of right rudder and it must be assumed that the nosewheels were in fact skidding on the icy runway. The maximum nosewheel steering angle is 6 deg from use of rudder pedals up to 40 kts. An override button on the hand tiller will allow nosewheel steering inputs of up to 75 degrees up to 20kts. It is not known whether the steering input was via pedals or hand tiller, but the prolonged rudder pedal input to the right suggests that hand tiller steering was not attempted (see note 6 above). There would be no aerodynamic effect from the rudder itself at such low speed. There was no input to either brake pedal at this point. The aircraft continued to increase in speed up to a maximum of 22 kts and the heading deviation continued to increase.
Both brake pedals were applied full at 21:36:18 and the aircraft came to a halt within 6 seconds. No differential braking was applied to counter the continuing swing. The brakes appeared effective in slowing the aircraft however; the anti-skid function is inoperative below 20kts. The aircraft came to a dead stop at 21:36:24. It is not possible to determine if the main wheels were skidding on the runway, although even with both brake pedals applied, the turn continued. The final heading was 312.89 degrees.
Park brake was applied at 21:36:41. The engines were shut down at 21:47:48 (No.2) and 21:47:53 (No.1).

The data forwarded to IAE contains limited engine data. There are no parameters for N1 speed, N1 vibration (all zeroes on engine 1), P2 (LPC inlet), P2.5 (LPC delivery), Pb (HPC delivery pressure) or P4.9 (Turbine exit pressure).
In the absence of these parameters the following postulations of the cause of the asymmetric acceleration are drawn:

1. *There may have been ice build up on the LPC blades, the LPC inlet guide vanes and the Fan Exit Guide Vanes. It is thought that due to the prolonged taxi phase, the 5 minute hold with the No.2 engine shielded from the prevailing wind by the fuselage and the No.1 engine used slightly off idle to assist the turn on to the runway, that this could have led to ice build up. There were no ice shedding engine manoeuvres prior to acceleration to take off thrust (FCOM SOP 3.03.09, P2).The reduction in inlet area may have led to a reduced flow through the engine which may have become choked. The choked flow would have limited Pb and hence the Pb controlled fuel flow and leading to a lower EPR on engine 1.*

2. *The fuel flow may have been restricted. There was no similar characteristic on the engine run after the event, or since the aircraft returned to service.*

The most probable cause was a build up of ice on the No.1 engine leading to restricted flow within the compressor which caused the asymmetric thrust. Under similar circumstances without ice on the runway, it would normally be possible to arrest any deviation from heading and keep the aircraft on the runway. Stabilising both engines at 1.05 EPR (50% N1) as per the FCOM (SOP 3.03.12, P1) prior to advancing the throttle levers to take-off thrust is likely to have allowed the pilot to determine an asymmetric thrust condition and will also have initiated ice-shedding.

FCOM 2.02.14, P2 states that the use of Flex take-off thrust is forbidden on a contaminated runway. Due to the low speed of this event, the use of flex thrust is not considered to have been a contributory factor. This procedure exists to maximise available stopping distance in the event of an engine failure prior to V1.

Finally, the aircraft was returned to service after rigorous checking after the incident. No engine or airframe defects were found. The aircraft is still in service with no repetition of the phenomenon.

Please feel free to contact me to discuss the findings.

Regards

Job Title: V2500 Service Specialist."

APPENDIX D

Airbus/company FCOM take off procedure.

A320/1/330 FLIGHTCREW OPERATING MANUAL	STANDARD OPERATING PROCEDURES TAKE OFF	3.03.12	P 1
		MYT	Oct 04

TAKEOFF

The minimum braking action for take off on the Airbus fleet is 'Medium' in all 3 sectors.

A330: If CM2 is to be PF, CM1 announce "You have control".
CM2 announce "I have control"

- **ANNOUNCE (PF)** .... **"TAKE OFF"**
- **BRAKES (PF)** .... **RELEASE**
  Rolling takeoff is recommended when possible to minimise risk of FOD ingestion.

☐ **If the crosswind is at or below 20 knots and there is no tailwind:**

- **THRUST LEVERS (PF)** .... **FLX or TOGA**

  To counter the nose up effect of setting engine takeoff thrust, apply half-forward stick until the airspeed reaches 80 knots. Release the stick gradually to reach neutral at 100 knots.

  For crosswind takeoffs, routine use of into-wind aileron is not recommended. In strong crosswind conditions, small amounts of lateral control may be used to maintain wings level but the pilot should avoid using excessive amounts. This causes excessive spoiler deployment, which increases the aircraft's tendency to turn into wind. PF adjusts engine thrust in two steps:

  - from idle to about 50 % N1 (1.05 EPR)
  - from 50% N1 to takeoff thrust.

A330 - from idle to about 50 % N1 (1.1 EPR)
In case of take off at airfields >800' amsl:
Brakes on, slowly advance the thrust levers to 1.03 EPR and stabilise for 3 seconds, release brakes and select take off power.

Once the thrust levers are set, the captain calls "My thrust levers" and keeps his hand on the thrust levers until the aircraft reaches V1. PF must not put his hand on the thrust levers below 400 ft AGL except in an emergency

APPENDIX E

Airbus/company FCOM cross wind limits.

A319/A320/A321 MY TRAVEL FLIGHT CREW OPERATING MANUAL	SPECIAL OPERATIONS FLUID CONTAMINATED RUNWAY	2.04.10 SEQ 001	P 11 REV 21

SPRAY PATTERN

There is a little chance of the engines ingesting fluid, which in any case should not jeopardize safety. The risk of ingestion is independent of the depth of the contaminant.

CROSSWIND

To optimize directional control during the low speed phase of the takeoff and landing roll and according to the reported braking action given by the control tower, it is not recommended to take off or to land with a crosswind component higher than :

R

<table>
<tr><th rowspan="2">Reported braking action</th><th rowspan="2">Reported runway friction coefficient</th><th colspan="2">Maximum crosswind (kt)</th><th rowspan="2">Equivalent runway condition **</th></tr>
<tr><th>Takeoff</th><th>Landing</th></tr>
<tr><td>Good</td><td>≥ 0.4</td><td>29 *</td><td>33 *</td><td>1</td></tr>
<tr><td>Good/medium</td><td>0.39 to 0.36</td><td>29</td><td>29</td><td>1</td></tr>
<tr><td>Medium</td><td>0.35 to 0.3</td><td colspan="2">25</td><td>2/3</td></tr>
<tr><td>Medium/poor</td><td>0.29 to 0.26</td><td colspan="2">20</td><td>2/3</td></tr>
<tr><td>Poor</td><td>≤ 0.25</td><td colspan="2">15</td><td>3/4</td></tr>
<tr><td>Unreliable</td><td></td><td colspan="2">5</td><td>4/5</td></tr>
</table>

* This is the maximum crosswind demonstrated for dry and wet runway.

** Equivalent runway condition (only valid for maximum crosswind determination)

1. Dry, damp or wet runway (less than 3 mm water depth)
2. Runway covered with slush
3. Runway covered with dry snow
4. Runway covered with standing water with risk of hydroplaning or wet snow

R 5. Icy runway or high risk of hydroplaning

APPENDIX F

Airbus/company FCOM contaminated runway definitions.

A319/A320/A321	SPECIAL OPERATIONS	2.04.10	P 1
MY TRAVEL FLIGHT CREW OPERATING MANUAL	FLUID CONTAMINATED RUNWAY	SEQ 001	REV 32

GENERAL

This section presents the recommendations of Airbus Industrie for operations from wet runways or from runways which are covered with contaminants such as standing water, slush or snow.

CAUTION

Take off from an icy runway is not recommended.

DEFINITIONS

DAMP : A runway is damp when the surface is not dry, but when the water on it does not give it a shiny appearance.

WET : A runway is considered as wet when the surface has a shiny appearance due to a thin layer of water. When this layer does not exceed 3 mm depth, there is no substantial risk of hydroplaning.

STANDING WATER : is caused by heavy rainfall and /or insufficient runway drainage with a depth of more than 3 mm.

SLUSH : is water saturated with snow which spatters when stepping firmly on it. I: is encountered at temperatures around 5° C and its density is approximately 0.85 kg/liter (7.1 lb/US GAL).

WET SNOW : is a condition where, if compacted by hand, snow will stick together and tend to form a snowball. Its density is approximately 0.4 kg/liter (3.35 lb/US GAL).

DRY SNOW : is a condition where snow can be blown if loose, or if compacted by hand, will fall apart again upon release. Its density is approximately 0.2 kg/liter (1.7 lb/US GAL).

COMPACTED SNOW : is a condition where snow has been compressed (a typical friction coefficient is 0.2).

ICY : is a condition where the friction coefficient is 0.05 or below.

The performance given in this chapter has been divided into two categories which are determined by the depth of the contaminant. For each of these categories an equivalent depth of contaminant has been defined for which the performance deterioration is the same.

1. WET RUNWAY and EQUIVALENT

Equivalent of a wet runway is a runway covered with or less than :

- 2 mm (0.08 inch) slush
- R 3 mm (0.12 inch) water
- 4 mm (0.16 inch) wet snow
- 15 mm (0.59 inch) dry snow

APPENDIX G

Airbus/company FCOM contaminated runway.

A319/A320/A321 MYTRAVEL FLIGHT CREW OPERATING MANUAL	SPECIAL OPERATIONS	2.04.10	P 2
	FLUID CONTAMINATED RUNWAY	SEQ 001	REV 36

2. CONTAMINATED RUNWAY

A linear equivalence between depth of slush and snow has been defined :

- 12.7 mm (1/2 inch) wet snow is equivalent to 6.3 mm (1/4 inch) slush
- 50.8 mm (2 inches) dry snow is equivalent to 6.3 mm (1/4 inch) slush

Note : 1. On a damp runway no performance degradation should be considered.

2. It is not recommended to take off from a runway covered with more than

R *4 inches of dry snow or 1 inch of wet snow.*

OPERATIONAL CONDITIONS

Performance penalties for takeoff as published in this section are computed with the following assumptions :

- The contaminant is in a layer of uniform depth and density over the entire length of the runway.
- Antiskid and spoilers are operative.
- The friction coefficient is based on studies and checked by actual tests.
- The screen height at the end of takeoff segment is 15 feet, not 35 feet.

In addition, for contaminated runways only :

- There is drag due to rolling resistance of the wheels.
- There is drag due to spray on the airframe and gears.
- Reverse thrust is used for the deceleration phase.
- Maximum thrust is used for takeoff.

Note : The net flight path clears obstacles by 15 feet instead of 35 feet.

APPENDIX H-1

MyTravel Airways (UK) Operations Manual braking action information.

Before leaving the facility, perform a flight control and flaps check whilst ground personnel observe control surface movement.

As soon as the aeroplane is clear of the facility, the air-conditioning may be switched ON again. Ensure that taxi and take-off checklists are completed. Prior to releasing brakes for take-off, accelerate the engines to verify their operation.

8.2.4.10 **Technical Log**

The commander is to confirm that, whenever de-icing has taken place, an appropriate entry is made and signed in the technical log. In particular, the fluid type/mix, start and completion times should be recorded.

If the de-icing has been conducted after closing the aircraft main doors or taxi through de-icing has been utilised, the Captain will confirm details with the de-icing crew and sign the remaining white (where retained on board) and pink pages. Engineering staff will then retain the de-icing certificate along with the off-loaded technical log page/pages.

If there is any subsequent departure delay, or further deterioration in the weather conditions, the Captain should use this information, together with that in the tables at para. 8.2.4.3 above to form a realistic idea of whether further de-icing may be required. **NB. holdover times are calculated from the start of the anti-icing process.**

8.2.4.11 **Take-off/Landing Prohibition**

Take-off is prohibited if any of the following conditions exist:

(a) snow, ice or frost deposits are adhering to the wings, control surfaces or engines;
(b) heavy fall of wet snow with ambient temperature around freezing point;
(c) freezing rain or drizzle unless adequately protected by anti-ice treatment;
(d) the runway braking is reported as "poor" (braking coefficient less than 0.25).

8.2.4.12 **Braking Action**

Codes and Co-efficients

Various types of measuring equipment may be used:

APPENDIX H-2

MyTravel Airways (UK) Operations Manual braking action information (continued).

DBV	Diagonal Braked Vehicle
SKH	Skiddometer (high pressure tire)
JBI	James Brake Index
SKL	Skiddometer (low pressure tire)
MUM	Mu-meter
TAP	Tapley Meter
SFT	Friction Tester

The codes and co-efficients below relate to those shown in field H of a SNOTAM report

CODE	BRAKING ACTION		CO-EFFICIENTS			
		SFT/TAP	MUM	SKH SKL	DBV	JBI
5	GOOD	.40	.45	.48	.50	.60
4	MEDIUM TO GOOD	39 - .36	.44 - .40	47 - .43	49 - .43	59 - .50
3	MEDIUM	35 - .30	39 - .33	42 - .36	42 - .36	49 - .40
2	MEDIUM TO POOR	29 - .26	32 - .27	35 - .30	35 - .31	39 - .26
1	POOR	25	26	29	30	25
9	UNRELIABLE					

8.2.4.13 Landing Prohibition

The minimum runway braking action is reported as POOR/MEDIUM/MEDIUM

APPENDIX I

FCOM engine anti ice procedures.

A320/1/330	STANDARD OPERATING PROCEDURES	3.03.09	P 2
FLIGHT CREW OPERATING MANUAL	AFTER START	MYT	Oct 04

- **PITCH TRIM (CM2)... SET**

  Set CG on pitch trim wheel.

> **A330:** For this purpose use CG indicated on ECAM.

- **ECAM STATUS (CM1 and 2) ....CHECK**

  Check no status reminder on the ECAM upper display. If status reminder displayed, press the STS pushbutton. Do not release the Ground mechanic before the Status is checked.

- **ENG ANTI ICE ....AS RQRD**

  NOTE: Icing conditions may be expected wher OAT (on ground), or TAT (in flight) is below +10°C and there is visible moisture in the air (such as clouds, fog with low visibility, rain, snow, sleet, ice crystals) or sanding water, slush, ice or snow is present on the taxiways or runway.

  <u>CFM:</u> If icing conditions last longer than 30 minutes, or if significant engine vibrations occurs, the engine should be accelerated to a least 70 % N1 for 30 seconds before operating at higher thrust. (See also parking brake limitation 3.01.32). If airport surface conditions and congestion do not permit accelerating the engine to 70 % N1, then power setting and time period should be as high and long as practical. This run up should also be performed just prior takeoff with particular attention to engine parameters to ensure normal engine operation. <u>Note: IGNITION memo appears on the ECAM as continuous ignition is automatically selected on older CFM engines only.</u>

  <u>V2500:</u> During ground operation when engine anti ice is required and OAT is +3° C or less, periodic engine run-ups to as high a thrust setting as practical (50 % N1 recommended) may be performed at the pilot's discretion to centrifuge any ice from the spinner, fan blades and low compressor stators. There is no requirement to sustain the high thrust setting. The run-ups should be performed at intervals not greater than 15 minutes. Subsequent take off under these conditions should be proceeded by a static run up to as high a thrust as practicable (50% N1 recommended) with observation of all primary parameters to ensure normal engine operation. IGNITION memo appears on ECAM as continuous ignition is automatically selected.

APPENDIX J

Airbus Industrie's policy on cold weather operations is described in a document named Getting to Grips with Cold Weather Operations. Conf. item 1.18.5.

The following is an excerpt from the document:

"………………

C3.1.2 Fluid contaminated runway: Water, slush and loose snow.

The reason for friction force reduction on a runway contaminated by water or slush is similar to the one on a wet runway. The loss in friction is due to the presence of a contaminant film between the runway and the tire resulting in a reduced area of tire/runway dry contact. As for the µwet, µcont is often derived from µdry. Again, until recently, regulations stated that µcont = µdry /4. This is applicable to A300/A310/A320/A321.

C3.1.3 Hard contaminated runway: Compacted snow and ice.

These two types of contaminants differ from water and slush, as they are hard. The wheels just roll over it, as they do on a dry runway surface but with reduced friction forces. As no rolling resistance or precipitant drag is involved, the amount of contaminant on the runway surface is of no consequence. Assuming an extreme and non-operational situation, it would be possible to takeoff from a runway covered with a high layer of hard compacted snow, while it would not be possible to takeoff from a runway covered with 10inch of slush. One can easily imagine that the rolling resistance and precipitation drag would be way too important. The model of the friction forces on a runway covered by compacted snow and icy runway as defined in the FCOM, leads to the following µ: Compacted snow : µ = 0.2. Icy runway: µ = 0.05

BRAKING PERFORMANCE

Please, bear in mind:

- *The presence of contaminants on the runway affects the performance by:*
  - A reduction of the friction forces (µ) between the tire and the runway surface,
  - An additional drag due to contaminant spray impingement and contaminant displacement drag,
  - Aquaplaning (hydroplaning) phenomenon.

- *There is a clear distinction between the effect of fluid contaminants and hard contaminants:*
  - Hard contaminants (compacted snow and ice) reduce the friction forces.
  - Fluid contaminants (water, slush, and loose snow) reduce the friction forces, create an additional drag and may lead to aquaplaning.

- *To develop a model of the reduced µ according to the type of contaminant is a difficult issue. Until recently, regulations stated that µwet and µcont can be derived from the µ observed on a dry runway (µdry/2 for wet runway, µdry/4 for water and slush).*

- *Nevertheless, recent studies and tests have improved the model of µ for wet and contaminated runways, which are no longer derived from µdry. The certification of the most recent aircraft already incorporates these improvements.*

C3.4.2 Difficulties in assessing the effective µ

The two major problems introduced by the airport authorities evaluation of the runway characteristics are:
-The correlation between test devices, even though some correlation charts have been established.
-The correlation between measurements made with test devices or friction measuring vehicles and aircraft performance.
-These measurements are made with a great variety of measuring vehicles, such as:Skiddometer, Saab Friction Tester (SFT), MU-Meter, James Brake Decelerometer (JDB),Tapley meter, Diagonal Braked Vehicle (DBV).
Refer to ICAO, Airport Services Manual, Part 2 for further information on these measuring vehicles.
The main difficulty in assessing the braking action on a contaminated runway is that it does not depend solely on runway surface adherence characteristics.
What must be found is the resulting loss of friction due to the interaction tire/runway.
Moreover, the resulting friction forces depend on the load, i.e. the aircraft weight, tire wear, tire pressure and anti-skid system efficiency.
In other words, to get a good assessment of the braking action of an A340 landing at150,000 kg, 140 kt with tire pressure 240 PSI, the airport should use a similar spare A340... Quite difficult and pretty costly!
The only way out is to use some smaller vehicles. These vehicles operate at much lower speeds and weights than an aircraft. Then comes the problem of correlating the figures obtained from these measuring vehicles and the actual braking performance of an aircraft. The adopted method was to conduct some tests with real aircraft and to compare the results with those obtained from measuring vehicles.
Results demonstrated poor correlation. For instance, when a Tapley meter reads 0.36, a MU-meter reads 0.4, a SFT reads 0.43, a JBD 12...
To date, scientists have been unsuccessful in providing the industry with reliable and universal values. Tests and studies are still in progress.
As it is quite difficult to correlate the measured µ with the actual µ, termed as effective µ, the measured µ is termed as «reported µ«.

In other words, one should not get confused between:
1/ Effective µ: The actual friction coefficient induced from the tire/runway surface

interaction between a given aircraft and a given runway, for the conditions of the day.
2/ Reported µ: Friction coefficient measured by the measuring vehicle.

Particularities of fluid contaminants
Moreover, the aircraft braking performance on a runway covered by a fluid contaminant (water, slush and loose snow) does not depend only on the friction coefficient µ.
As presented in chapters C2.2 and C2.3, the model of the aircraft braking performance (takeoff and landing) on a contaminated runway takes into account not only the reduction of a friction coefficient but also:
- The displacement drag
- The impingement drag
These two additional drags (required to be taken into account by regulations) require knowing ***the type and depth of the contaminant.***
In other words, even assuming the advent of a new measuring friction device providing a reported µ equal to the effective µ, it would be impossible to provide takeoff and landing performance only as a function of the reported µ. Airbus Industrie would still require information regarding the depth of fluid contaminants.

C3.4.3 Data provided by Airbus Industrie

Please refer to § C6 for further details on contaminated runway performance provided by Airbus Industrie.

Hard contaminants
For hard contaminants, namely compacted snow and ice, Airbus Industrie provides the aircraft performance independently of the amount of contaminants on the runway. Behind these terms are some effective µ. These two sets of data are certified.

Fluid contaminants
Airbus Industrie provides takeoff and landing performance on a runway contaminated by a fluid contaminant (water, slush and loose snow) as a function of the depth of contaminants on the runway.
For instance, takeoff or landing charts are published for «1/4 inch slush», «1/2 inch slush», «1/4 inch water» and «1/2 inch water». For loose snow, a linear variation has been established with slush.

In other words, pilots cannot get the performance from reported µ or Braking Action. *Pilots need the* ***type and depth of contaminant*** *on the runway.*

CORRELATION BETWEEN REPORTED µ AND BRAKING PERFORMANCE

Please, bear in mind:
Airports release a friction coefficient derived from a measuring vehicle. This friction coefficient is termed as «reported µ».
The actual friction coefficient, termed as «effective µ» is the result of the interaction tire/runway and depends on the tire pressure, tire wear, aircraft speed, aircraft weight and anti-skid system efficiency.

To date, ***there is no way to establish a clear correlation between the «reported μ» and the «effective μ».*** *There is even a poor correlation between the «reported μ» of the different measuring vehicles.*
It is then very difficult to link the published performance on a contaminated runway to a «reported μ« only.
The presence of ***fluid contaminants*** *(water, slush and loose snow) on the runway surface* ***reduces the friction coefficient****, may lead to* ***aquaplaning*** *(also called hydroplaning) and creates an* ***additional drag.***
This additional drag is due to the precipitation of the contaminant onto the landing gear and the airframe, and to the displacement of the fluid from the path of the tire. Consequently, braking and accelerating performance are affected. The impact on the accelerating performance leads to a limitation in the depth of the contaminant for takeoff.
Hard contaminants *(compacted snow and ice) only affect the braking performance of the aircraft by a reduction of the* ***friction coefficient.***
Airbus Industrie publishes the takeoff and landing performance according to the ***type of contaminant****, and to the* ***depth*** *of fluid contaminants."*

APPENDIX K

AIBN has extracted some of BAE Systems' views on icing certification. (Conf. item 1.18.6).

"*Aircraft Certification for Contaminated runway*

Operation
•No testing required
•Compliance material is still being developed
• JAA are in the process of approving new rule NPA 25B,G-334 for compliance with 25X1591. Sent to JAA HQ 1st Sept 2002.
•Replaces NPA25B,D,G- 244 as published in JAR25 change 15
•No corresponding FAR requirement so there has been no rule harmonisation.
• Any AFM or MOM information may be advisory material dependant on the relevant certification basis.

Runway Condition and Braking Definitions

• ICAO
Damp, Wet, Water Patches, Flooded
• JAR Ops 1.480
Dry, Damp, Wet, Contaminated
• JAA Certification
Water, Slush, Wet Snow, Dry Snow, Compacted Snow, Specially Prepared Winter Runway, Ice
•Manufacturer
Slippery? Contaminant depth?
•ATC
Good, Medium, Poor, nil

JAR Ops Contaminant Definitions

• ***Dry Runway** - A dry runway is one which is neither wet nor contaminated, and includes those paved runways which have been specially prepared with grooves or porous pavement and maintained to retain "effectively dry" braking action even when moisture is present. !!!!!!*

•***Runway contaminated by standing water, slush or loose snow** - A runway is considered to be contaminated when more than 25% of the runway surface area (whether isolated or not) within the required length and width being used, is covered by surface water, more than 3mm deep, or by slush, or loose snow, equivalent to more than 3mm of water.*

Aircraft Certification for Contaminated runway

Operation
•No testing required
•Compliance material is still being developed
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compliance with 25X1591. Sent to JAA HQ 1st Sept 2002.
•Replaces NPA25B,D,G- 244 as published in JAR25 change 15
•No corresponding FAR requirement so there has been no rule harmonisation.
• Any AFM or MOM information may be advisory material dependant on the relevant certification basis.

Certification Friction Levels

•Performance data on contaminated runways can be based on either test evidence or the minimum conservative default values given below.*

Contaminant	***Default Friction Value*** ***μ***
Standing Water, Slush and Wet Snow	$= -0.0632\left(\frac{V}{100}\right)^3 + 0.2683\left(\frac{V}{100}\right)^2 - 0.4321\left(\frac{V}{100}\right) + 0.3485$ where V is groundspeed in knots Note 1 Braking Force = load on braked wheel x μ Note 2 For V greater than the aquaplaning speed, use μ = 0.05 constant
Compacted Snow	0.2*
Sanded Snow	No default value can be given as the friction level to be assumed is based on actual measurement
Dry Snow	0.17*
Ice	0.05*

Operational requirements

• JAR Ops 1.490 & 1.520
-A limitation prohibiting take-off is also compliant
-Requires consideration of appropriate approved data
• ATC rely on runway friction devices and reports from other crews
-Both can provide incorrect or confusing information
•Runway Friction Measurement Devices
-No International standard for Friction devices
-Accuracy of friction devices depends on contaminant type and design of device
- No correlation to Certification friction levels or IATA terminology
•Crew Reports
-Level of "friction" is based on retardation and is therefore aircraft type specific
• Advisory Information in MOM (FCOM)

Conclusions

- *There is no overall accepted “certification to operational correlation” between mu meters and airplanes.*

- *Contaminated runway operation continues and overruns will happen.”*