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Report C 1998:03e

Accident involving aircraft SE-DMX,
9 March 1997,
Kiruna airport, BD county, Sweden

L-16/97

This is an English translation of the Swedish final report. If there are any discrepancies caused by the translation, the Swedish version is valid

1998-02-18 L-16/97

Swedish Civil Aviation
Administration

601 79 NORRKÖPING

Report C 1998:03E

The Swedish Board of Accident Investigation has investigated an accident which occurred on March 9:th 1997 at Kiruna airport, BD county, Sweden, involving an aircraft with registry SE-DMX.

In accordance with section 14 of the Ordinance on the Investigation of Accidents (1990:717) the Board submits herewith a final report of the investigation.

Olle Lundström Monica J Wismar

Henrik Elinder Jan Mansfeld

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APPENDICES

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Aircraft: registration and type	**SE-DMA,** McDonnell Douglas DC-9-81
Owner/Operator	Finova Capital Limited 11 Albermarle Street, London W1X 3HE, England/ Scandinavian Airlines System Frösundaviks Allé 1, 161 87 Stockholm
Date and time of occurence	09-03-1997 at 7.06 p.m. in darkness *Note:* All times in the report are given in Swedish normal time (SNT) = UTC + 1 hour.
Place of occurence	Kiruna airport, BD County, (pos 6749N 2020E; 459 meters above sea level)
Type of flight	Scheduled traffic
Weather	*Reported during approach:* Wind 250°/22 knots max 32 knots in gusts, visibility 10 kilometers in light snow, cloud base 2 000 ft, temp./dew-point +2°/-1° Celsius, QNH 996 hPa. *Reported on short final:* Wind 270°/32 knots, visibility 4 000 meters
Persons on board: crew	2/3
passengers	151 inclusive a child under the age of 2
Injuries to persons	One passenger was seriously injured during evacuation of the aircraft
Damage to aircraft	Limited
Other damage	A runway light was broken
Captain´s age and license	50 years, Airline Transport Pilot's License (Swedish)
Captain´s total flying hours	8,685 hours, of which 5,883 on the type
Captain´s flying hours and number of landings previous 90 days	143 hours, all of which on the type
First officer´s age and license	37 years, Commercial Pilot's License with Instrument Rating (Swedish)
First officer´s total flying hours	4,370 hours, of which 3,419 on the type
First officer´s flying hours and number of landings previous 90 days	159 hours, all of which on the type
ATC Controller	The ATC Controller was qualified

The Board of Accident Investigation (SHK) was notified on March 9:th 1997 that an accident with an aircraft registered SE-DMX had occurred at Kiruna airport, BD county, on the same day at 7.06 p.m.

The accident has been investigated by SHK represented by Olle Lundström, chairman, Monica J Wismar, chief investigator flight operations, Henrik Elinder, chief technical investigator (aviation), and Jan Mansfeld, chief investigator rescue services.

The Board has been assisted by Lars Laurell as medical expert.

The investigation was followed by the Swedish Civil Aviation Administration represented by Max Danielsson.

The purpose of the investigations performed by SHK is solely to prevent accidents and incidents in the future.

SUMMARY

After a flight from Stockholm/Arlanda, the aircraft, route number SAS 1042, was about to land at Kiruna airport. The captain was the pilot flying and the first officer was the non-flying-pilot. When the aircraft was approaching Kiruna the pilots were informed that runway 21 was in use and had braking coefficients 0.36, 0.32, 0.32 with 100% ice on the runway, which had been sanded. The co-pilot acquired visual contact with the runway at approximately 500 – 600 feet above the ground. There was turbulence and heavy snowfall during the approach. The captain crabbed the aircraft into the wind and shortly before touchdown on the runway he removed the crab towards the runway heading. The landing was performed with the automatic brake system set on medium brake effect and the Anti-Skid System activated.

In connection with the reverse thrust after touchdown the captain believed that the aircraft swerved to the right. He then unreversed and steered the aircraft in the direction of runway heading. At the same time he requested maximum brake effect. The aircraft then began to drift towards the left edge of the runway, without him being able to prevent it from doing so. Approximately 1,500 meters down the runway the aircraft departed the left edge of the runway and continued parallel to the runway for approximately 400 meters until it came to a stop in half- meter deep snow.

An emergency evacuation of the aircraft was performed and the crew estimated that the evacuation had taken 60-70 seconds. An elderly passenger received a shoulder injury and had to be carried from the aircraft on a stretcher.

The investigation shows that deviations occurred, from the airport regulations and rescue service instructions, as well as from the airline’s operative instructions.

The accident was caused by the following main factors:

- Gusty winds, with speeds exceeding the average wind speed with more than 10 knots, were not reported;
- Recommended crosswind speed limitation was exceeded;
- The aircraft touched down more than nine meters to the left of the runway centerline;
- The braking action coefficient was less than that which had been reported.

Recommendations

SHK recommends The Swedish Civil Aviation Administration to:

- ensure that air traffic control personnel are given more in-depth flight operational instruction and the possibility of joint training with flight crew personnel, and to
- ensure that routines and equipment are developed to enable ATC personnel to report information concerning actual crosswind component upon request.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 *The accident*

The aircraft, with route number SAS 1042, departed Stockholm/Arlanda Airport the 9:th of March 1997 at 17:38 hours with 151 passengers and five crewmembers aboard, on a flight to Kiruna airport. The captain was the flying pilot and the first officer was the non-flying pilot during the flight. After the departure from Arlanda via the reporting point KARLA the flight proceeded direct to Kiruna VOR at flight level (FL) 330 (approximately 10,000 meters). When the aircraft approached Kiruna the pilots contacted Kiruna tower and received the following weather information: Wind 250 degrees at 22 knots, gusting 32 knots, visibility 10 km. in light snow, cloud base 2000 feet, temperature/dew- point $+2^{o}/-1^{o}$ centigrade, QNH 996 hPa. They were further informed that runway 21 was in use and that the braking action was 0.36, 0.32, 0.32 , and that the runway was covered by 100% ice and sanded. The pilots performed a Localizer and Distance Measuring Equipment (LLZ+DME) approach procedure with the autopilot engaged.

During the approach the tower controller reported that the visibility had decreased to 4000 meters in snow showers. After the aircraft had passed the outer marker OP inbound the tower reported that the wind was 270^{o}/32 knots and issued the aircraft landing clearance on runway 21.

The crew acknowledged the landing clearance but neither the captain nor the co-pilot recognized the change in the wind direction in relation to the earlier wind report. The copilot obtained visual contact with the runway at approximately 500-600 feet above the ground.

During the approach it was turbulent and the snowfall was heavy. The captain noticed, when he disconnected the autopilot, that the aircraft drifted to the left, which he corrected for. He crabbed the aircraft into the wind and just prior to touch-down on the runway he turned the nose onto the runway heading. The automatic braking system was set for medium braking effect (“MED”) and the Anti Skid System was activated (see 1.6.2).

Immediately after touchdown the captain pushed the steering column forward and reversed the engines. The copilot verified that the ground spoilers extended and that the automatic braking system was functioning. In connection with application of reverse thrust the captain felt that the aircraft yawed to the right. He then discontinued the reverse thrust and steered the aircraft onto the runway heading, simultaneously requesting maximum braking effect (“MAX”) as he felt that the aircraft was not noticeably decelerating. Thereafter the aircraft began to drift towards the left runway edge, something he could not prevent. Roughly 1,500 meters down the runway the aircraft departed the left runway edge and continued parallel with the runway approximately 400 meters before coming to a stop. The deceleration was very smooth in the ½ meter deep snow.

When the aircraft had come to a stop the copilot informed the tower of what had taken place. The captain ordered an emergency evacuation and action was taken in accordance with the emergency checklist.

The accident took place at 19:06 hours at location 6749N 2020E; 459 meters above sea level.

1.1.2 *The evacuation*

The purser, whose position was in the forward part of the cabin, entered the flight deck when the aircraft had come to a stop and at that time received the emergency evacuation order. She called-out on the loud speaker system (Public Announcement – PA) “Evacuation, evacuation, open seat belt, open seat belt, get out, get out”. Thereafter she opened both forward emergency exits and urged the passengers to quickly exit the aircraft. The right forward emergency exit (service door) was unusable as the wind from that direction blew the escape slide up vertically, which blocked the exit. All four over-the-wing exits were opened by passengers. The aft emergency exits were opened by the two cabin crew members with aft cabin positions. The crew estimated that the evacuation took between 60 and 70 seconds. The purser and the captain verified that there were no remaining persons on board before exiting the aircraft themselves.

When the crew got outside the aircraft the passengers had already began to walk towards the terminal building, a distance of about one kilometer. A few unaccompanied minors were assisted by a passenger who was an employee of the airline. An elderly passenger had received a shoulder injury during the evacuation and required a stretcher. A number of passengers were in shock and freezing when they arrived at the terminal building. Before everyone was gathered, a few passengers had already left the terminal. The crew gathered together the remaining passengers and the captain informed the group about what had taken place.

1.1.3 *The rescue services*

Due to the prevailing weather conditions the watch commander of the airport rescue force ordered “increased readiness” and sounded “warning alarm” prior to the aircraft landing. When the tower controller became aware of the fact that the aircraft had departed the runway she triggered the accident alarm. The alarm sounded over the alarm system but the siren at the fire station building did not sound due to the fact that the control relay had not been reset after the prior warning alarm. This must be accomplished manually. As the fire fighting personnel were outside the building and did not hear the alarm, the tower controller had to contact the watch commander on the radio in order to give the alarm notice. Thereafter she contacted the central air rescue coordination center (ARCC) and notified them that an aircraft accident had occurred and that they required an ambulance for a passenger with assumed heart trouble. ARCC promised to arrange an ambulance and contacted the county emergency center (SOS) in Luleå. The emergency operator was informed that the airport rescue service was not in the need of assistance and that all the passengers had evacuated the aircraft. The community (Luleå) rescue services were therefore never called out. ARCC did however convey a request that the police should be summoned in order to prevent any passengers from getting lost on the airport.

When the airport rescue force arrived at the aircraft the watch commander judged that the aircraft needed to be secured with a layer of foam around the fuel tanks, which was accomplished. Two ambulances arrived at the airport at approximately 19:30 hours. The attendants in one of these attended to the wounded passenger.

1.2 Injuries to persons

	Crew	*Passengers*	*Other*	***Total***
Fatal	-	-	-	**-**
Seriously injured	-	1	-	1
Slightly injured	-	-	-	-

No injuries	5	150	-	155
Total	**5**	**151**	**-**	**156**

The number of passengers includes a child under the age of 2.

1.3 Damage to aircraft

Limited.

1.4 Other damage

A runway edge light was broken.

1.5 Personnel information

The captain
Flying hours

previous	*24 hrs*	*90 days*	*Total*
All types	-	143	8, 685
This type	-	143	5, 883

The first officer.
Flying hours

previous	*24 hrs*	*90 days*	*Total*
All types	-	159	4, 370
This type	-	159	3, 419

1.6 Aircraft information

1.6.1 *General*

Owner/Operator:	Finova Capital Limited 11 Albermarle Street, London W1X 3HE, England/ Scandinavian Airlines System Frösundaviks Allé 1, 161 87 Stockholm
Type:	McDonnell Douglas DC-9-81
Serial number:	48002
Year of manufacture:	1981
Gross weight:	Max allowed T/O-weight 64 410 kg (142 000 lbs.) Actual T/O weight 60 448 kg (133 265 lbs.) Actual landing weight 55 848 kg (123 124 lbs.)
Center of gravity:	Within allowed boundaries (16% MAC/LIZFW 21 at T/O)
Engine manufacture:	Pratt & Whitney
Engine model:	JT8D-217C (JT8D-219 derated)
Number of engines:	2
Fuel loaded before event:	Jet A1 (Uplift: 5,632 kg, T/O fuel: 8,600 kg, Trip fuel: 4 600 kg)
Aircraft flying time:	
Aircraft cycles:	38,547 hrs./36,337 cycl.

Number of cycles since latest periodic check:	MSC/3D: 4 hrs./5 cycl.	
Engines operating time:	Engine #1, S/N 696395	Engine#2, S/N 708149
Time/cycles total:	32,421 hrs./22,364cycl	34,408hrs./26,049cycl.
Time/cycles since O/H:	19,492hrs./12934cycl	20,147hrs./17,410cycl.
Time/cycles since S/V:	12,415hrs./8,069cycl.	10,587hrs./8,691cycl.

The aircraft had a valid Certificate of Airworthiness.

1.6.2 *The brake system*

The aircraft-type is equipped with an Automatic Braking System (ABS). With the help of a lever on the instrument panel, the ABS can be programmed prior to landing for three different brake effects; "MIN", "MED", and "MAX". With "MIN" or "MED" selected the brake system will be activated about three seconds after the extension of the wing spoilers and will apply the brakes automatically, even if the engines are reversed, so that a constant retardation of 4.0 ft/s^2 (1.2 m/s^2) or 6.5 ft/s^2 (2.0 m/s^2) respectively, is attained. If "MAX" has been pre-selected the system will be activated after about one second and produce maximum braking effect on the main wheels irregardless of reverse thrust. In addition to ABS the pilots can always manually brake by depressing the brake pedals on the top of the rudder pedals.

The brake system also includes a function to prevent wheel locking (Anti Skid System). This system is normally always activated but may be deactivated manually.

1.7 Meteorological information

1.7.1 *The airport forecast (Terminal Aerodrome Forecast, TAF, and Meteorological Report, METAR)*

A deep low pressure center was moving east across the Arctic Ocean, resulting in very strong and gusty westerly winds across northernmost Sweden. Snow showers drifted from the mountains down to the interior of the country. The weather information that the pilots utilized in their initial flight planning on the 9:th of March 1997 was issued for Kiruna in the form of TAF and METAR and was as follows:

TAF

	UTC	Av. Wind	Gusts	Visib	Weather	Clouds
ESNQ[1]	15-22	25025kts	35kts	>10 km		[2]SCT 2 500ft
AMD[3]	16-22	25025kts	35kts	>10 km		SCT 2 500ft
TEMPO[4]	16-22			1 500	[5]SHSN	[6]BKN 1 000ft

The TAF valid from 18-22 was the same as the above.

METAR

UTC	Wind	Gust	Visib.	Weather	Clouds	Temp/dp	QNH
1550	25027kts	39kts	4000	SHSN	BKN 2 000ft	01/M01	Q0996
1620	25020kts	33kts	>10 km	SHSN	SCT 3 000ft	02/M01	Q0996

[1] ESNQ ICAO identifier for Kiruna airport
[2] SCT 3 to 4 octaves cloud cover (scattered)
[3] AMD Amended meteorological report
[4] TEMPO Temporary
[5] SHSN Moderate snow showers
[6] BKN 5 to 6 octaves cloud cover (broken)

					BKN15 000ft		
1650	25027kts	<37kts	>10 km	[7]VCSH	SCT 2 500ft	01/M01	Q0996
					BKN15 000ft		
1720	23022kts	<32kts	>10 km		SCT 3 000ft	02/M01	Q0995
1750	25025kts	<35kts	>10 km	[8]-SN	SCT 2 000ft	02/M01	Q0996

The wind reported in METAR indicates an average value during a ten minute period. Wind gusts are reported if the maximum speed during the ten minute period exceeds the average speed by 10 knots or more.

Through the cloud base reporting one can discern that a snow shower passed the field between 1900 and 1910hrs.

1.7.2 *Wind*

The airport at Kiruna is equipped with the Swedish Civil Aviation Administration's (LFV) automatic weather station (SAVO). The anemometers are placed 300 meters inside the runway threshold for each runway. The wind direction and speed on runway 21 at the time of the accident is graphically presented in appendix 2. The calculated wind direction and speed per one-minute intervals is presented in the table below.

Time	Average wind direction (°)	Average wind speed (knots)	Maximum wind speed (knots)
18:50	250	25	36
19:00	250	30	42
19:04	260	30	48
19:05	270	33	42
19:06	270	31	42 (landing)
19:07	260	34	42
19:10	270	31	38
19:15	270	30	35

1.8 Aids to navigation

Runway 21 is equipped with an Instrument Landing System (ILS). At the time of the accident the glide path function (GS) was off the air and only Localizer and DME was available.

1.9 Communications

The radio-communications between the aircraft and Kiruna tower are presented in appendix 5.

1.10 Aerodrome information

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[7] VCSH Snows showers in the vicinity of the airport
[8] -SN Light snowfall

Kiruna airport had operational status in accordance with the Swedish AIP (Aeronautical Information Publication)

1.11 Flight recorders

1.11.1 *General*

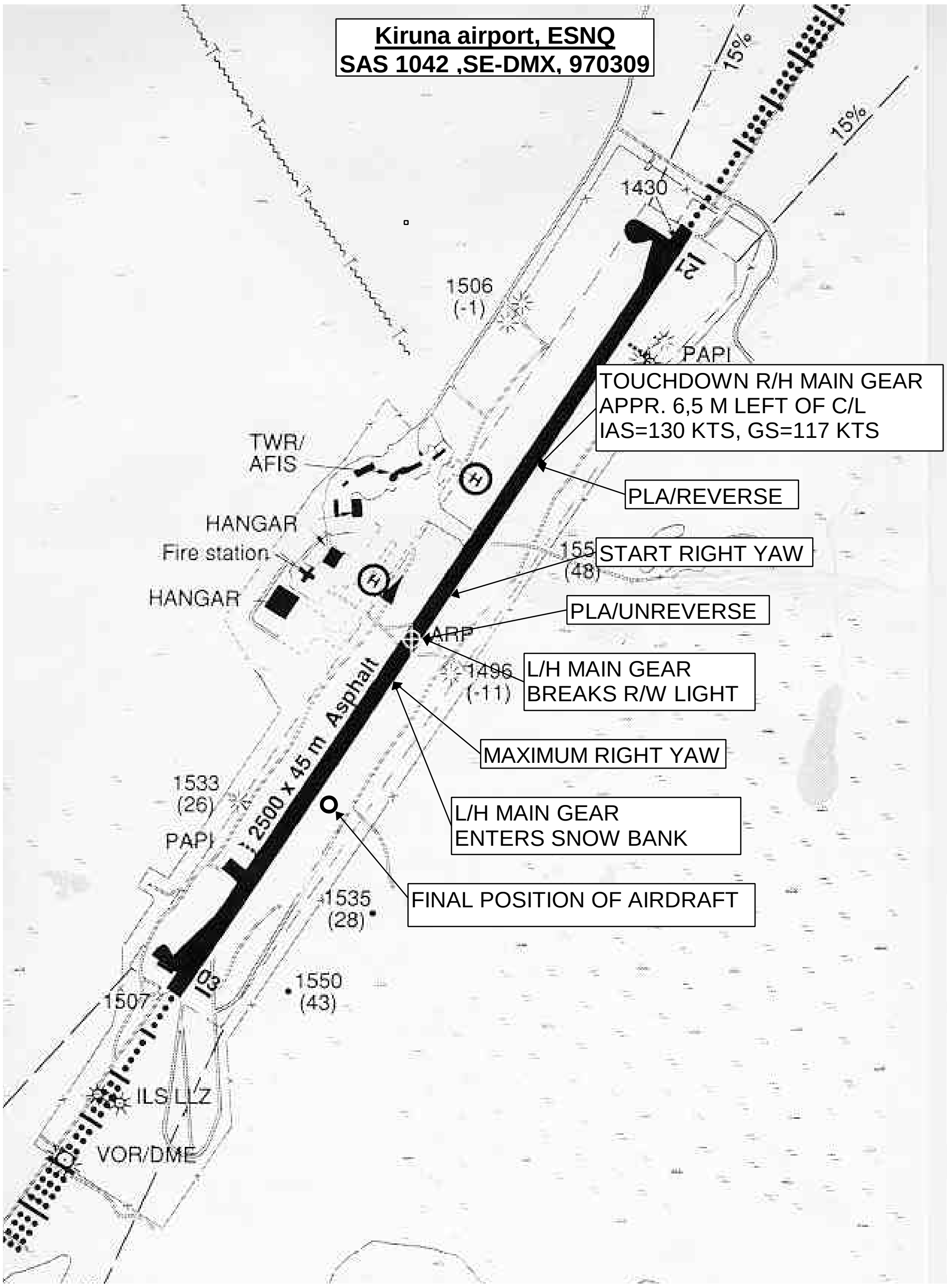
The aircraft was equipped with a flight recorder (Digital Flight Data Recorder-DFDR) and a voice recorder (Cockpit Voice Recorder-CVR). Subsequent to the accident these were played back by SAS in Copenhagen under supervision by the Danish Board of Civil Aviation Accident Investigation. All references to time in the DFDR and CVR transcriptions use the time of the aircraft's touchdown as the zero time.

1.11.2 *DFDR*

More than 100 perimeters, with varying frequencies. were registered during the approach and up to the time that the pilots, according to the emergency checklist, turned off the electrical supply to the system. The recording of speeds under 30 knots is not reliable with the air data system and is therefore not registered. Groundspeed and the position on the runway have been calculated with help of the recorded longitudinal acceleration. The DFDR parameters essential to the analysis are graphically represented in appendix 3.

The lateral excursion (the aircraft's position with respect to the centerline) and the heading along the runway is graphically presented in appendix 4.

The measurements of the runway and the essential positions and occurrences along it are depicted on the airport map below.



1.11.3 *CVR*

Essential portions of the internal communications in the aircraft have been written out and presented, as is all radio traffic, in appendix 5. The time frame is from approximately five minutes prior to touchdown on the runway until the electrical supply is turned off.

1.12 Accident site and aircraft wreckage

1.12.1 *The accident site*

Tire tracks in the snow showed that the aircraft touched down approximately 720 meters down runway 21. The touch down took place on the right hand main gear 6.5 meters to the left of the runway centerline. The width between the main gear is 5.1 meters. After touchdown the aircraft rolled approximately 1160 meters before it came to a stop about 620 meters from the opposite runway threshold and about 18 meters outside the runway edge. During the final 400 meters the aircraft traveled along the side of the runway through snow about 0.5 meters in depth.

1.12.2 *Aircraft Wreckage*

Minor damage occurred on the left-hand nose wheel system, the left wing flap and the tail cone. This damage was temporarily repaired at the airport and thereafter the aircraft was ferry flown to SAS's Oslo base for final repair.

1.13 Medical information

Nothing indicates that the mental and physical condition of the crew or the ACT controller had been impaired prior to the occurrence.

1.14 Fire

There was no fire.

1.15 Survival aspects

The deceleration of the aircraft in the snow was gentle and the aircraft emergency locator was not activated. During the emergency evacuation via the slides an elderly passenger fell and injured her right shoulder. Among the other passengers a few were slightly shocked and chilled during the walk to the terminal building in the cold wind.

1.16 Tests and research

1.16.1 *Technical investigation of the brake system*

The Auto Brake System and the Anti Skid System were examined after the accident. Nothing emerged that indicated a system failure.

1.16.2 *Asymmetrical reverse thrust*

From the DFDR transcription it is apparent that engine reverse thrust was asymmetrical after touchdown. Despite the fact that both throttle levers were moved to the normal reverse position (PLA- 20°), normal reverse effect was only acquired on the left engine. The highest reverse effect registered for the left, respective right engine was 1.385 EPR[9] respective 1.131 EPR. The difference was caused by a rigging discrepancy in the mechanical engine control system.

1.17 Organisational and management information

1.17.1 *General*

The airline SAS pursues heavy national and international air traffic. The head office is located in Stockholm, where operational management is also stationed. There are a

[9] EPR Engine Pressure Ratio=Thrust

number of manuals concerning operations.

1.17.2 *Flight Operations Manual(FOM)*

The FOM states the airline's general routines for all operational activities.

- Under section 3.3.1 special corrections and safety measures are described that are to be taken during landing on slippery or contaminated runways with respect to different weather and runway conditions.
- Under subsection 3.2 of the above it is stated that the reported friction coefficients shall be considered as unreliable if the temperature at the airport is close to 0°C and there is standing water, slush, or wet snow on the runway; provided the friction measurements have not been accomplished a Skiddometer Friction Tester/BV11 or a SAAB/Surface Friction Tester.

1.17.3 *Aircraft Operations Manual MD-80 (AOM)*

The AOM states specific instructions and operative limitations with regard to the aircraft type.

In section 1.14, paragraph 2.4 the function and use of the Automatic Brake System is described. SHK has not found any special directions within these instructions concerning the changing of the selected brake effect while braking is in progress. Section 3.3/8 treats the different operational factors in conjunction with landing.

- Paragraph 3 describes, among other things, the phenomenon of "Tail blanking", which can arise in connection with the use of reverse thrust on aircraft with tail-mounted engines. "Tail blanking" arises when the reversed airstream from the engines disturbs the airflow over the aircraft's aft fuselage, which diminishes the longitudinal aerodynamic stability and rudder effect. The phenomenon increases as speed decreases and can be specially critical on slippery runways.

- Paragraph 5.3 describes landing techniques on slippery runways. If the braking coefficient is less than "GOOD", automatic braking in "MED" or "MAX" is recommended with engine reverse thrust to maximum 1.60 EPR as soon as the nose wheels touch the ground.

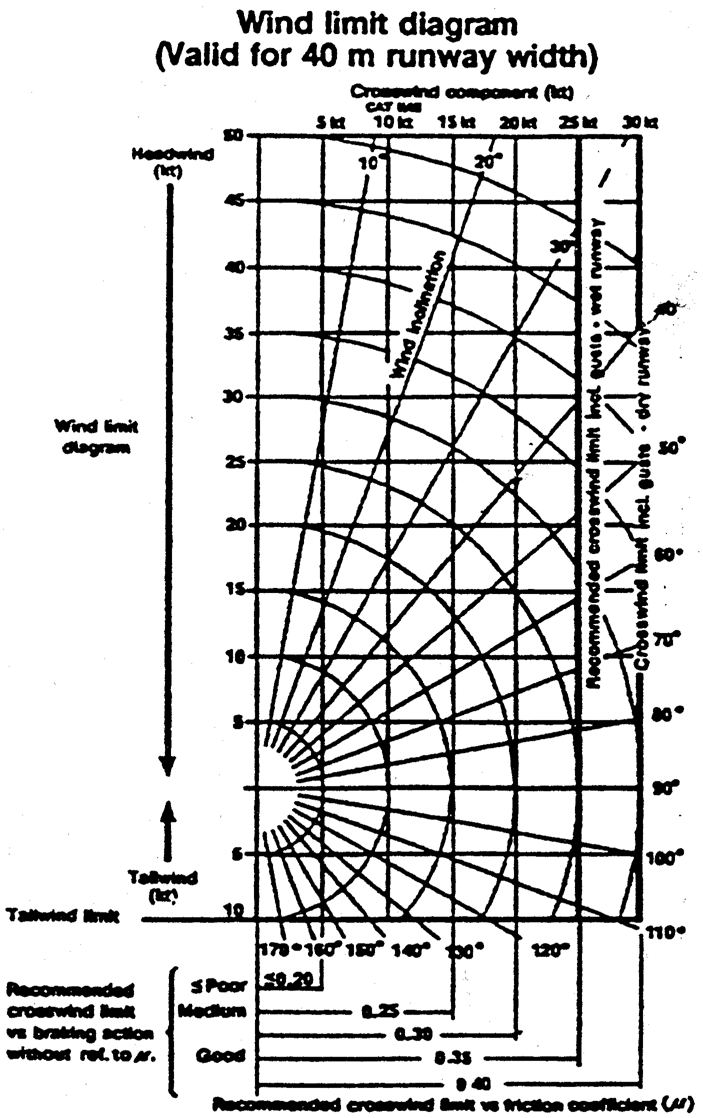
- Paragraph 6.2 describes steps that should be taken in the event the aircraft drifts to the side or yaws after touchdown. In such instances it is recommended that engine reverse be discontinued in order to avoid the diminishment of longitudinal aerodynamic stability as a result of "Tail blanking".

- In the same paragraph it is pointed out that the simultaneous application of brakes and use of forward elevator should be avoided under such circumstances, as this also can reduce the aircraft's natural directional stability down the runway.

1.17.4 *SAS route manual*

The SAS route manual states specific company rules and regulations for flying within the SAS route net.

-In chapter GWC MD-80, page 2.8.2 the limits for takeoff and landing with respect to wind direction/speed and reported friction coefficients are given. These limits are compiled in the Wind limit diagram shown below, which is also included in the aircraft checklist.



Wind limit diagram (actual size 33 x 66 mm)

From the diagram, the maximum allowed crosswind component[10] can be found for landing on a runway with a reported friction coefficient of 0.32. It is 22 knots, which on runway 21 at Kiruna corresponds to an actual wind of 250°/42 knots or 270°/25 knots.

A landing in gusty winds of 270°/48 knots requires a friction coefficient of >0.40.

1.17.5 *Cabin Operations Manual (COP)*

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[10] Crosswind component – the component of the surface wind that is at right angles to the runway centerline

The COP states general rules, routines and regulations for cabin personnel. In these it is stated how each crew member shall act during an emergency evacuation. Orders that are given to passengers, shall be given in a clear and distinct voice. The choice of language shall be either English or one of the Scandinavian languages depending upon which is most suitable considering the nationality of the passengers. Both languages may be used for Scandinavian passengers.The order that shall be given is “Emergency – Open seat belt – Get out”. One should strive for a rapid evacuation even if there are no signs of fire.

The first officer is to leave the aircraft after the evacuation order is given and direct the passengers to a safe location in the vicinity of the aircraft. The captain shall be the last to leave the aircraft after having first insured himself that there is no remaining person onboard.

1.17.6 *Crew Resource Management (CRM)*

The concept of CRM, in short, refers to the optimal use of knowledge and resources that are accessible within an air crew to attain maximum safety, effectiveness and comfort during a flight. In CRM great emphasis is placed on communication between the crew members and on how one goes about in order to attain good cooperation and a “team spirit”, onboard as well as outside the aircraft. Since 1989 SAS trains it’s flying personnel in CRM. Everyone is given a basic course in the subject and thereafter complimentary training is given the pilots in connection with the periodical flight training (PFT), which takes place biannually.

1.18 Additional information

1.18.1 *The runway conditions at Kiruna airport*

1.18.1.1 *Snow removal and measurement of braking coefficient*

The runway conditions at Kiruna airport had been troublesome during the day with a variety of rain and wet snow falling on the ice covered runway and varying temperature around 0°C. At 17:47 p.m. snow removal on the runway was initiated with a combined plow-sweep-and blow machine, a so-called “PSB”. After the snow removal the runway was still covered with ice and the field master therefore decided that the runway should be sanded with warm sand. In order to sand the entire runway, the sanding truck, which had a sanding width of approximately 15 meters, had to first drive up and down the runway on either side of the centerline and then once back and forth along the outer edges of the runway. The sanding was initiated about 18:30 p.m. and was complete around 15 minutes later.

Subsequent to the sanding the braking coefficient was measured with measuring equipment of type Skiddometer Friction Tester/BV11, which gave the coefficients 0.32, 0.32, and 0.36 for runway segments A, B, and C respectively. According to the Civil Aviation Administration’s (LFV) “Rules of Civil Aviation” (BCL) this braking coefficient nomenclature corresponds to; “medium”, “medium”., and “good to medium”. This information was forwarded to the tower controller by the field master. Due to the low friction value the field master decided that the runway should be sanded once again, which was initiated around 18:50 p.m.

A spot test of the runway friction coefficient, that was done after the second sanding, showed that the average had increased to 0.38. This sanding was, however discontinued after the round trip up and down the runway centerline, as the aircraft was then on final for landing.

When the sand truck exited the runway it was snowing heavily and the driver attempted to contact the field master, who was responsible for measuring and reporting the braking action. He was unable to gain contact as the field master was inside the terminal building and was occupied with baggage handling. Instead the driver reported directly over the radio to the tower controller, "You now have a completely white runway so I don't have a clue as to what the braking action is". The tower controller responded with a "Yes".

About 25 minutes after the accident, a reading was taken of the runway braking coefficient and the following readings were registered; 0.38, 0.35 and 0.34, corresponding to "good to medium", "medium" and "medium".

Concerning measurement and reporting of runway coefficients in the BCL, (BCL-F 3.2) it is prescribed, among other things, that measurements shall be accomplished in both runway directions 5-10 meters on either side of the centerline. Further it is stated that a new measurement shall be done as soon as there is reason to believe that the current readings on any of the runway's three sectors have changed by more than 0.05 units or more. The measured values shall be given as unreliable when the results are unsure, for example if the runway is covered with wet snow or the test vehicle's speed was less than 95 km/hr.

(Measurement and reporting of runway braking action has been treated specially in SHK's report C 1997:36).

1.18.1.2 *BCL/BFT*

SHK has observed that there are differences concerning the nomenclature of runway braking action in the two regulatory works, BCL and BFT (Regulations for Air Traffic Control Service). In the BCL, braking action in the interval 0.39 to 0.36 is labeled as "Good to Medium", whereas in the BFT, the equivalent friction coefficients are said to be "Medium to Good".

1.18.2 *Wind mensuration at Kiruna airport*

The regulations for wind mensuration equipment at airports is described in BCL-F 3.7, paragraph 7. At Kiruna airport there are, as earlier mentioned, two sensors installed that measure the wind speed and wind direction. Each sensor is connected to "transmission equipment" (TEQ) that computes the momentary wind (average wind during a five second period), the two-minute wind average and the ten-minute wind average. Furthermore the maximum and minimum values for speed and direction are registered during the preceding 10 minutes.

Each TEQ transmits computed wind values each fifth second to presentation equipment in the airport tower (BPU). On the BPU the wind information is presented from each sensor for the selected time period.

1.18.3 *Regulations for air traffic control service*

The working routines for air traffic controllers at civilian airports are presented in the instruction document BFT.

In BFT section 10, paragraph 4.3.2.3.1 the following is stated concerning the reporting of surface wind direction and speed to arriving aircraft:

> "a) The direction shall be given in degrees magnetic and the speed in km/hr. or kts. Average values shall cover the two minute period prior to the observation/reading, if the aircraft has not requested otherwise.

If the wind instrumentation does not provide readings of two minute average winds, the momentary wind may be given.

b) Variation in direction shall be given, when the total variation amounts to 60 degrees or more and the average speed exceeds 10 km./hr. (5kts.). It shall be given with the two direction extremities between which the wind varies.
c) Speed variations (wind gusts) shall be given, when the maximum speed exceeds the average wind speed by 20 km./hr (10kts.) or more. Only the maximum value need be given, if the aircraft has not requested otherwise."

In section 10, paragraph 4.3.2.3.2 the following is stated concerning visibility values:

"b) When significant variations in the visibility in different directions occur, additional values shall be given stating the direction of observation. Here special attention shall be paid to the visibility in the takeoff direction in connection with departing aircraft, and to the visibility in the approach and landing area in connection with arriving aircraft.

Section 4, chapter 2, paragraph 3.2 states what information shall be given to aircraft initiating final approach:

"a) significant changes in the average value of the speed and direction of the surface wind;
b) the latest information available concerning wind shear and/or turbulence in the final approach area;
c) prevailing visibility in the direction of approach and landing"

According to paragraph 3.3, the following information shall be transmitted without delay to aircraft on final approach:

"c) significant variations in the prevailing surface wind expressed in minimum and maximum values;

Note Extreme values of wind direction and speed are, where appropriate, taken from the actual meteorological report (QAM), except when the variations observed on the anemometer exceed these values.

d) significant changes in the runway conditions" and
"f) changes in readouts for RVR or visibility in the approach and landing direction."

1.18.4 *Witness statements*

1.18.4.1 *The cabin crew*

The cabin crew perceived the evacuation as proceeding relatively well despite the fact that it was unprepared and that there was not time to inform the passengers about where they should proceed after they had exited the aircraft. The cabin crew, consisting of a Danish purser and two Swedish flight attendants, gave the emergency evacuation order in English. They had to raise their voices in order to get the passengers to leave their hand baggage onboard.

The ground stop in Kiruna was to be short and the crew was then to fly back to Stockholm. Therefore the cabin crew kept their indoor shoes on and did not put on any outdoor garments for the ground stop. This resulted in their loss of shoes when they got out into the deep snow and difficulties in walking across the slippery runway and into the terminal building. The runway edges were experienced as very slippery.

The two flight attendants in the aft part of the cabin had no conception of the number of Unaccompanied Minors (UM) onboard or where they were sitting.

When the crew met the airport rescue force outside the aircraft they could not determine who was in command as the watch commander had no distinctive markings.

Once inside the terminal building the crew had the feeling that the ground personnel there had not been informed about what had occurred. Passenger check-in to Stockholm proceeded as usual. An arriving passenger who had asthma symptoms, asked for oxygen, but this was not procurable inside the terminal building.

1.18.4.2 *The passengers*

The majority of the passengers thought that the emergency evacuation went relatively smoothly. A few thought that the purser’s shrill voice and the orders in English were confusing and aroused a feeling of panic. There was no information given as to what to do outside the aircraft. They felt that it took a long time for the rescue personnel to get to the accident site. Several of the passengers were without their outdoor garments when they started off to the terminal building in the cold wind, and during the walk they became terribly chilled. When they arrived at the terminal building there was no one there to receive them. After a while the crew arrived. The captain informed them about what had happened in Swedish.There were English-speaking persons among the passengers that did not understand but they later received help with a translation by fellow-travellers. The passengers were in want of information about how they should get their baggage and several of them left the terminal building without information. The number of passengers was never verified.

1.18.4.3 *The ATC controller*

The traffic controller in the Kiruna tower had worked as a controller since September 1995 and at the time of this occurrence was alone in the tower. She has stated that during the day the wind had varied from almost calm to strong gusts.Likewise, the weather had been varying from light snowfall to heavy snow showers. When the driver in the sanding truck reported to her that the runway was “white” and that he was doubtful about earlier reported friction coefficients on the runway, she did not consider that to be the correct information channel for the reporting of friction coefficients and for that reason did not take any special steps She has said that she had been taught that possible changes of the runway braking action shall be reported by the fieldmaster to be valid for forwarding to departing and arriving aircraft.

Prior to the landing she reported to the aircraft that the visibility was reduced and that snow showers were in progress. In connection with the landing clearance she reported the wind to be 270°/32 knots. The wind recording instrumentation was at that time set for the two-minute average wind. Thereafter she concentrated on whether the aircraft should land or go-around. She didn’t realize that any great changes in the wind took place during the latter part of the aircraft’s approach.

1.18.4.4 *The airport personnel*

The personnel inside the terminal building did not receive any immediate alarm that the aircraft had departed the runway and that there had been an emergency evacuation of the aircraft. The measures taken by them were therefore somewhat delayed. When they were informed of the situation, they then performed their work in accordance with the emergency checklist, Local Aircraft Accident Procedure (L-AAP). A head-count of the passengers was not accomplished as several of them had already left the airport. Subsequent to this occurrence the L-AAP has been revised.

1.18.5 *Regulations regarding rescue services*

Regulations for rescue services at approved airports are stated in BCL-F 3.4 Equivalent regulations were included in Kiruna airport's rescue instruction.

The accident in question is defined in the instruction as "Aircraft crash with known crash site (Red action plan)". According to the instruction the traffic control shall in the case of "Red action plan", as the first measure, trigger the accident alarm. The second step shall be to alert the community rescue services which, in accordance with the rescue service law (1986:1102) has the main responsibility for the rescue force in the case of an aircraft accident with a known accident site.

If an accident takes place on the airport during good visibility and surface conditions, it is the airport fire-brigade's duty to initiate the rescue effort within 90 seconds after the sounding of the alarm. The airport watch commander shall contact the community rescue commander and inform him of the situation and lead the effort until such time as the rescue commander takes the responsibility.

The sixth measure stated is that ARCC shall be informed so as to assist, if required, the community rescue commander in, for example arranging helicopter transport for severely injured persons etc.

The medical evacuation system is under the jurisdiction of the county council and the calling of an ambulance is normally done through SOS Alarm AB (i.e. 911).

2 ANALYSIS

2.1 The landing

It was evident from the weather reports that the pilots received prior to and during the flight from Stockholm that the landing at Kiruna airport could very well be difficult, with snowfall and gusty westerly winds up to 35-39 knots. When they approached the airport they received detailed weather information with the actual braking action on runway 21. The crew determined, with the help of the company wind limit diagram (ref. 1.17.4), that the reported wind direction and speed did not exceed the applicable maximum values for landing, taking into account the prevailing braking action.

During the approach the Kiruna tower reported that snow showers were in progress and that the visibility had diminished. Due to the snowfall the crew first attained contact with the runway at 500-600 feet above the ground instead of a height of 2000 feet as they had expected. When disconnecting the autopilot the captain noted that the aircraft drifted-off to the left, which he corrected for. The information that the wind direction had shifted from 250°to 270°, which the tower controller reported in connection with the landing clearance, was not perceived by the pilots. This indicates that the landing took place under harsh conditions which demanded their total attention. The landing was made more difficult by the existence of strong wind gusts that had not been reported.

If the pilots had understood the change in the wind direction and had had the possibility of checking the new direction on the wind limit diagram, they would have found that the crosswind component now exceeded the recommended value for landing with the prevailing runway braking coefficient. But even if the pilots had perceived the message, it would hardly have been possible for them to accomplish that check at this late phase of the landing. With the thought in mind that the pilots were aware that the landing conditions were difficult, they should have requested complimentary information from the controller during the approach regarding momentary wind and runway condition.

When faced with marginal landing conditions, generally pilots should well prior to the approach, when necessary, request complementary weather and runway information, determine and mentally prepare themselves for the valid limiting values. By doing so, a decision to abandon an approach shortly before landing in the event of the deterioration of one or more landing parameters could be accomplished quicker and safer. SHK is furthermore of the opinion that the wind limit diagram in use should be able to be made clearer and easier to use.

But even with an easily used wind limit diagram it can be difficult in practice to determine a crosswind component if the landing takes place during gusty crosswinds in darkness and limited visibility. Under such circumstances it would be of great help to the pilots if the traffic controller, in addition to informing about the wind direction and speed, could, upon request also give the current crosswind component. This already is in practice within military aviation. The information can be easily determined by the controller manually but there is also technical equipment available where the crosswind component is presented automatically, as with the wind direction and wind speed.

The touchdown of the aircraft on the runway took place more than 9 meters left of the centerline. From the DFDR transcription it can be seen that the pilot reversed the engines according to normal routine immediately after touchdown. About 8 seconds after touchdown, when the aircraft began to yaw to the right he terminated engine reverse, which is recommended in the AOM to decrease the risk of so-called “Tail blanking”. “Tail blanking” was however probably not the cause of the yaw to the right as the indicated speed (IAS) at this time was still approximately 100 knots and the phenomenon generally occurs at low speeds.

With the help of rudder input the pilot was able to arrest the right-hand yaw after about 7 seconds. After that the aircraft began to yaw to the left and to drift towards the left edge of the runway. The pilot was unsuccessful in gaining control of the aircraft before it slid off the runway and out into the unplowed area to the left of it, slightly less than 20 seconds after touchdown.

Furthermore it can be determined from the DFDR transcription that the retardation of the aircraft increased directly after touchdown to maximum 0.2 g (6.4ft./s^2), which correctly corresponds to the retardation that the ABS, preselected to “MED” should produce (ref. 1.6.2). Thereafter the retardation decreased in two “steps” before the aircraft departed the runway and was slowed by the snow. The first decrease occurred with reverse thrust still activated and was probably caused by the fact that the runway braking action, when the aircraft approached the left edge, was no longer sufficient (ref. 2.2) for the aircraft’s brake system (ABS + Anti Skid System) to achieve the selected retardation of 6.5 ft./s^2., i.e. the aircraft’s main wheels were partially skidding against the runway. The point in time of the second decrease in retardation, roughly 12 seconds after touchdown, coincides well with the time when the pilot terminated the engine reverse.

The pilot’s attempt to increase the retardation by switching the ABS from “MED” to “MAX” probably had little if any effect on the sequence of events as the main wheels were already skidding with the ABS set on “MED”. His forward column (elevator) input after touchdown was a deviation from the AOM. Due to the fact that forward elevator input (AND) during a high-speed ground roll results in decreased loading on the main gear and increased loading on the nose gear; this measure can have involved a decrease of the available wheel-brake effect. Together with the skidding this could have even decreased the aircraft's natural directional stability on the runway.

During engine reverse thrust only the left engine produced normal reverse effect.This asymmetrical reverse force gave rise to a certain yaw effect to the left in the aircraft. The fact that, despite this, the aircraft yawed to the right indicates that this was less significant in comparison to the yaw effect to the right caused by the crosswind component's "weather-vane" effect across the horizontal stabilizer. In addition to the yaw effect the crosswind caused an aerodynamic force on the aircraft which strived to displace it to the left.

Already at touchdown the aircraft was in excess of 9 meters to the left of the centerline which meant that the distance from the left main wheel to the edge of the runway at that time was about 11 meters. This margin was too small, with the prevailing crosswind and runway braking friction, for the captain to have the time to straighten-out the aircraft before the left main wheel ran into the snow bank.

2.2 The runway conditions

The initial sanding of the runway was done after it had been cleared with the "PSB" and was initiated a little less than 40 minutes prior to the landing. At this time the runway was covered with ice and the subsequent measurement of the braking action produced such a bad result that the field master decided upon another sanding. The low friction value after the earlier sanding can, according to the field personnel, have been due to the fact known from experience that warm sand can sometimes melt in "too deep" into the ice if the ice temperature, as in this case, is close to 0°C.

The field master's decision on further sanding was therefore correct. The effect of the second sanding however was marginal. Partly because there was only time to sand along the runway centerline before the aircraft was to land, and partly due to the fact that wet snow started falling so that the runway was "totally white" when the sanding was terminated. The runway was therefore covered by a mixture of ice, ice with encapsulated sand, sand and wet snow when the aircraft landed. The actual runway braking action was therefore extremely uncertain but surely worse than that which had been reported to the aircraft. This was specially valid along the outer ¼ of the runway, that had only been sanded once, that is to say the portion of the runway that the aircraft ended up on shortly after touchdown. That the true runway friction coefficient was worse than that measured was also feared by the driver of the sand truck when he exited the runway. That the runway was really very slippery was also experienced by the onboard passengers during their walk to the terminal building.

With the difficult landing conditions that prevailed it would have been of great value for the pilots if they had been informed of the true runway condition. Even if they had received the information late during the approach they would have had a greater possibility to adapt the landing to the prevailing situation or to make a decision about abandoning the landing.

The field master, who is responsible for measurement and reporting of braking action, should, with the prevailing weather conditions, have engaged himself in that main task instead of working with baggage handling in the terminal. As there was an obvious reason to presume that the braking action within some sector of the runway had worsened with more than 0.05 units and the runway was covered with wet snow, there was therefore a deficiency in the actions of the airport personnel and a deviation from BCL-F 3.2, paragraph 8, in that the runway braking action was not reported as "unreliable".

2.3 Air traffic control

In the final wind report prior to landing that the traffic controller gave to the aircraft, the wind was stated to be 270^0/32 knots. From the transcript that was made of the airport's automatic weather station it is evident however that large variations in the force of the wind occurred shortly prior to and during the landing. The average wind speed was then 30-34 knots but gusts with wind speeds of up to 48 knots occurred.

As stated in section 2.1 the strong crosswind was of great importance for the chain of events during the landing. It would have therefore been of great value to the pilots if they had been informed about the wind gusts that occurred shortly prior to landing and that they could expect during the landing. The traffic controller should have therefore more carefully followed-up the wind variations and according to the BCL, should have informed the landing aircraft that wind gusts occurred that exceeded the average wind speed with more than 10 knots.

That the traffic controller, in connection with the aircraft landing, did not follow-up and report either the deterioration of the runway braking action or the strong wind gusts, gives the impression that she was not really aware of the great help that the controller can be to the pilots in demanding situations. Contributing to this can be the fact that she was relatively inexperienced in her position and did not have any personal flying experience or insight into pilot's working conditions. With greater insight into flight operations she would have known that many times it is better for the pilots to receive information that can be superfluous than not to receive information that can be of a decisive nature for the flight.

SHK assumes that there are several traffic controllers on the job who do not have requisite knowledge of pilots working conditions. There is therefore good reason to give traffic controllers a more in-depth instruction in operational flying and the possibility of joint training with flying personnel regarding communication and co-operation in a manner liking that which takes place in so-called CRM-training. With better knowledge and understanding of the respective partner's working situation, the air traffic controllers and pilots as a "team" could well facilitate each other and therewith enhance flight safety.

2.4 The evacuation

When the aircraft came to a stop the captain ordered an emergency evacuation which was correct considering that one did not know if the risk of a fire existed. According to SHK's assessment the evacuation was correctly carried out and was in accordance with applicable instructions.The evacuation time was also under the required 90 seconds.

SHK finds it however strange that the evacuation order to the passengers over the loud speaker system was only given in English. With the thought in mind that this was a purely domestic flight and the majority of the passengers probably were Swedish citizens, it would have been suiting that the order was even given in a Scandinavian language.

2.5 The rescue services

As soon as the traffic controller understood that the aircraft had run off the runway she, as a first measure, tripped the accident alarm at the airport in accordance with the airport rescue instruction. Due to the fact that the alarm did not sound at the fire station building's siren and that the watch commander was outside the building, the action from both the rescue service personnel and from the personnel inside the terminal building was delayed. This resulted in the prescribed reaction time not being attainable. That the siren's control relay had not been reset after the earlier warning alarm, constituted therefore a deficiency in the routines of the rescue service.

As a second step the traffic controller contacted ARCC and not the community rescue service, as is prescribed in the rescue instruction when an aircraft accident with known accident site has taken place. The community rescue service was not contacted by the airport watch commander either.

ARCC shall be notified first as the sixth point in the rescue plan, as ARCC in this case does not have any task concerning investigation or rescue. To utilize ARCC to alert the ambulance service was therefore an unnecessary detour in the alerting chain. The ambulance should have been sent for via SOS Alarmering AB according to normal routines.

The deficiencies discovered in the rescue services had no great significance for the chain of events here, but could, in another accident situation, lead to negative consequences.

3 CONCLUSIONS

3.1 Findings

a) The pilots were qualified to perform the flight.
b) The ATC controller was qualified as a controller.
c) The aircraft was airworthy.
d) The landing took place during difficult meteorological conditions.
e) An extra sanding was done near the runway centerline.
f) The reported runway braking action and wind speed on the runway was non-current and incomplete.
g) A deviation was made from BCL-F 3.2 concerning the runway condition.
h) The pilots did not perceive the final wind report prior to landing.

i) The pilot did not request complementary information about wind and runway conditions.
j) Recommended crosswind limit was exceeded.
k) The aircraft touched down approximately 9 meters to the left of the runway centerline.
l) The pilot's action subsequent to touchdown of pushing the control column forward was a deviation from the AOM.
m) The airport rescue service reaction was delayed due to the lack of an auditory siren.
n) The prescribed reaction time for the rescue service was not attained.
o) Several deviations were made from the airport's rescue instruction.
p) Technical failures, that affected the chain of events, were not ascertained on the aircraft.

3.2 Causes of the accident

The accident was caused by the following main factors:
- Gusty winds, with speeds exceeding the average wind speed with more than 10 knots, were not reported.
- Recommended crosswind speed was exceeded.
- The aircraft touched down more than nine meters to the left of the runway centerline.
- The braking action coefficient was less than that which had been reported.

4 RECOMMENDATIONS

SHK recommends The Swedish Civil Aviation (LFV) to:

- ensure that air traffic control personnel are given more in-depth operational flight instruction and the possibility of joint training with flight crew personnel, and to
- ensure that routines and equipment are developed to enable ATC personnel to report information concerning actual crosswind component upon request.