Runway overrun, Incident involving aircraft G-FLTA at Arvidsjaur airport, BD County, Sweden, on the 22nd of February 2002

Micro-summary: **Following touchdown in poor weather, this BAe 146 ran off the end of the runway.**

Event Date: **2002-02-22 at 1219 UTC**

Investigative Body: **Swedish Accident Investigation Board (AIB), Sweden**

Investigative Body's Web Site: **http://www.havkom.se/**

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ISSN 1400-5719

Report RL 2003:08e

Incident involving aircraft G-FLTA at Arvidsjaur airport, BD County, Sweden, on the 22nd of February 2002

Dnr L-006/02

SHK investigates accidents and incidents with regard to safety. The sole objective of the investigations is the prevention of similar occurrences in the future. It is not the purpose of this activity to apportion blame or liability.

Translated from the original Swedish by Dennis Lynn Anderson;
at the request of The Board of Accident Investigation.

In the event of discrepencies between the English and the Swedish texts, the Swedish version is to be considered the aurhoritative version.

The report is also available on our Web site: www.havkom.se

Statens haverikommission (SHK) Board of Accident Investigation

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2003-03-17 L-006/02

Swedish Civil Aviation Administration

601 79 NORRKÖPING

Report RL 2003: 08e

The Board of Accident Investigation (Statens haverikommission, SHK) has investigated an incident that occurred on the 22nd of February 2002 at Arvidsjaur airport, BD County, Sweden, involving an aircraft with registration G-FLTA.

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

Göran Rosvall

Monica J. Wismar Henrik Elinder

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APPENDICES

Abbreviations

AAIB	Air Accident Investigation Branch
ADF	Automatic Direction Finder/Finding Equipment
AFIS	Aerodrome Flight Information Service – *A service with the duty of issuing information of relevance to aircraft at un-controlled airports*
AFM	Aircraft Flight Manual
AGL	Above Ground Level
ATPL (A)	Airline Transport Pilot License (Aeroplane)
BAe	British Aerospace
°C	Degrees Celsius
CG	Center of Gravity
COM	Communications
CVR	Cockpit Voice Recorder
DA/DH	Decision Altitude/Decision Height
DME	Distance Measuring Equipment
DP	Decision Point
E	East
FL	Flight Level
ft	Feet
g	Acceleration force
GP	Glide Path
GS	Ground Speed
G/S	Glide Slope
h/hrs	Hour/hours
hPa	Hectopascal
IAL	Instrument Approach and Landing Chart
IAS	Indicated Air Speed
ILS	Instrument Landing System
JAA	Joint Aviation Authorities
JAR	Joint Aviation Regulations
JAR-OPS	JAR of Flight Operations
kg	Kilogram
kHz	Kilohertz
KIAS	Knots Indicated Air Speed
km	Kilometer
kt	Knot
LFV	Civil Aviation Administration (Swedish)
LLZ	Localizer
LOC	Localizer/Locator
Ltd	Limited
m	Meter
MA/MH	Minimum Altitude/Minimum Height
MAC	Mean Aerodynamic Chord
MAP	Manifold Absolute Pressure (in inches of mercury)
mm	Millimeter
MOM	Manufacturer's Operational Manual
MSL	Mean Sea Level
N	North
NAV	Navigation/Navigator
NDB	Non-directional Radio Beacon
NM	Nautical Mile
OM	Outer Marker
PC	Proficiency Check
PIC	Pilot in Command
PNF	Pilot Not Flying
QFE	Altimeter subscale setting to obtain elevation above airdrome
QNH	Atmospheric pressure at mean sea level
s	Second
SMHI	Swedish Meteorological and Hydrological Institute
SOP	Standard Operating Proceedures
TAS	True Air Speed
TL	Transition Level
UTC	Universal Time Coordinated
VOR	Very High Frequency Omnidirectional Radio Range
Vref	Reference speed (IAS) for threshold passage
W	West

Rapport RL 2003:08e

L-006/02
Report finalized 2003-03-17

Aircraft; registration, type	G-FLTA, BAe 146-200
Class,airworthiness	Normal, valid certificate of airworthiness
Owner/Operator	Westall Ltd./Flightline Ltd.
Date and time	22 February 2002, 13:19 hours in daylight *Note:* All times in this report refer to Swedish Standard Time = (UTC + 1 hour)
Place of occurrence	Arvidsjaur airport, BD County, Sweden, (pos. 6535N 01916E; 379 m above sea level)
Type of flight	Charter
Weather	According to SMHI's analysis at 13:20 hours: wind 180°/15 knots with gusts from 25–30 knots, visibility 5–10 km in light snow, clouds 8/8 with the ceiling at approximately 1,500 feet, temp./dew point –3/–6 °C, QNH 963 hPa.
Persons on board: Crew	2/4
Passengers	53
Injuries to persons	None
Damage to aircraft	Limited
Other damage	A runway threshold light was damaged
The aircraft commander:	
Gender, age, certificate	Male, 32 years old, ATPL (A)
Total flying time	5,400 hours, of which 3,890 hours on the type
Flying hours previous 90 days	35 hours, all on the type
Number of landings previous 90 days	24
The first officer:	
Gender, age, certificate	Male, 59 years old, ATPL (A)
Total flying time	11,000 hours, of which 1,500 hours on the type
Flying hours previous 90 days	42 hours, all on the type
Number of landings previous 90 days	38
Other crew members	3 cabin attendants and a flight mechanic

The Board of Accident Investigation (SHK) was notified on the 22nd of February 2002 that an incident involving an aircraft with registration G-FLTA had taken place at Arvidsjaur airport, BD County, Sweden, on that same day at 13:19 hours.

The incident has been investigated by SHK, represented by Olle Lundström, Chairperson until the 15th of September, and by Göran Rosvall, Chairperson from the 16th of September 2002, Monica J. Wismar, Chief Investigator Flight Operations and Henrik Elinder, Chief Technical Investigator (Aviation).

The investigation has been followed by the Swedish Civil Aviation Administration through Max Danielsson and Daniel Hummerdal.

Accredited representative from AAIB in England has been Peter Sheppard.

Summary

The aircraft, a Bae 146-200, was to land at Arvidsjaur airport. Prior to the approach the pilots received the following weather information from the AFIS personnel in the tower: wind 190 degrees at 11 knots, gusting to 21 knots, visibility 10 kilometers in light snow, overcast clouds at 1,400 feet, temperature –3 degrees, dew point –6 degrees, QNH 964 and TL 65. Approximately ten minutes later, when the aircraft was 41 NM south of the airport, they received a wind report of 190 degrees at 13 knots with gusts to 22 knots and QNH 963. At this time they also received information that the runway was sanded, that patches of ice were present on the runway and that the braking coefficients were reported to be 49, 49, 48.

The first officer was flying the aircraft. His initial intention was to turn to the east from the northerly course towards the airport and subsequently perform a straight-in ILS to runway 30. After discussion between the pilots, the approach was instead performed as a right-hand procedure turn to the runway 30 ILS.

According to the pilots the approach and touchdown took place without problems. However, subsequent to the touchdown they felt that aircraft speed retardation was not normal despite hard braking. As the aircraft approached the end of the runway they were not able to prevent the aircraft from colliding with a runway threshold light and continuing off the runway.

SHK states in the investigation that, among other things, the prerequisites for landing were marginal and that deficiencies existed in the airline's operational routines and the pilots' preparations prior to the landing. The investigation also addresses the problem that in certain cases measured braking action does not always seem to be representative of the actual ability of the aircraft to decelerate with wheel braking and sees the need for further research within this area.

The incident was probably caused by the following contributory factors:
– The landing prerequisites were marginal.
– The touchdown speed was somewhat too high.
– The touchdown took place far down the runway.
– The initial wheel braking was applied moderately.
– The reduction of engine thrust after touchdown was delayed.
– The aircraft may have been affected after touchdown by strong wind gusts that temporarily increased the tailwind component.
– The actual braking action was probably worse than that which had been reported.

Recommendations

The Civil Aviation Administration is recommended to – through the international cooperation among aviation authorities – work for that research is initiated on the mechanisms involved during wheel braking of commercial aircraft on contaminated runways, with the intention of obtaining more reliable information concerning an aircraft's actual braking ability in relation to the measured braking action. *(RL 2003: 08e R1)*

1 FACTUAL INFORMATION

1.1 History of the flight

The aircraft, a BAe 146-200 with flight number DLH 5185 took off from Hannover in Germany for a charter flight to Arvidsjaur in Sweden. The flight proceeded normally and the first officer was the flying pilot. When the aircraft was approaching Arvidsjaur, approximately 25 minutes prior to the planned landing, the pilots contacted the AFIS personnel at the airport and requested the latest weather report. The following information was received: wind 190 degrees at 11 knots, gusting to 21, visibility 10 kilometers in light snow, overcast clouds at 1,400 feet, temperature –3 degrees, dew point –6 degrees, atmospheric pressure QNH 964 and TL 65.

About ten minutes thereafter the pilots reported that they were descending to 6,000 feet and that their position was 41 NM south of the airport. At this time they received a wind report of 190 degrees at 11 knots with gusts up to 22 knots and QNH 963. At this time they also received information that the runway was sanded, that patches of ice were present on the runway and that the braking coefficients were reported to be 49, 49, 48.

Prior to the approach both pilots had agreed that they would perform an ILS approach and landing on runway 30. The first officer's intention was to turn to the east from the northerly course towards the airport and subsequently join the runway 30 ILS using a left turn-on. The aircraft commander had planned that they should perform a ”full procedure”, entailing that they should initially pass overhead the approach beacon ”AS” immediately southeast of the runway and thereafter perform a so-called right-hand procedure turn to join the ILS to runway 30. When this discrepancy had been sorted out, the aircraft had descended down to an altitude of 3,000 feet and they decided to perform the approach according to the aircraft commander's planning.

According to the pilots, the approach proceeded normally and shortly after touchdown the first officer applied wheel braking. Initially the braking took place with moderate brake pressure, taking into consideration passenger comfort. However, a few moments later, when he felt that the speed retardation of the aircraft was not normal, he increased the brake pressure. The pilots heard that the so-called Anti Skid System[1] was activated but the expected retardation was not forthcoming, even when full brake pressure was applied. When the aircraft approached the end of the runway the aircraft commander also applied full brake pressure, even this without noticeable effect upon the retardation. Thereafter the pilots were not able to prevent the aircraft from colliding with a runway threshold light and continuing off the runway. Ultimately the aircraft came to a stop slightly more that 80 meters beyond the runway threshold on a level and snow- covered stopway.

None of the persons on board were injured and after a short period of time everyone was able to disembark the aircraft from the position where it came to a stop.

The incident took place on the 22nd of February 2002, at 13:19 hours, at position 6535N 01916E; 379 meters above sea level.

[1] Anti Skid System – Lock-free brakes

1.2 Injuries to persons

	Crew	*Passengers*	*Other*	*Total*
Fatal	–	–	–	–
Seriously injured	–	–	–	–
Slightly injured	–	–	–	–
No injuries	6	53	–	59
Total	6	53	–	59

1.3 Damage to aircraft

Limited.

1.4 Other damage

A threshold light on runway 12 was damaged.

1.5 The crew

1.5.1 The aircraft commander

The aircraft commander was 32 years old at the time a held a valid ATPL (A) license.

Flying hours			
previous	*24 hours*	*90 days*	*Total*
All types	~	~	5,400
This type	~	35	3,890

Number of landings this type previous 90 days: 24.
Flight training on the type completed in 1999 at Flightline Ltd.
Latest PC carried-out 2002-02-11 in the BAe 146 simulator.

1.5.2 The first officer

The first officer was 59 years old at the time and held a valid ATPL (A) license.

Flying hours			
previous	*24 hours*	*90 days*	*Total*
All types	~	~	11,000
This type	~	42	1,500

Number of landings this type previous 90 days: 38.
Flight training on the type completed in 1999 at Flightline Ltd.
Latest PC carried-out 2002-01-20 in the BAe 146 simulator.

1.5.3 Other crew members

Three cabin attendants were on-duty in the cabin. They were employed in 1999 and 2000 respectively. A flight mechanic, employed by the company, was on board. His duties included the preparation of the aircraft for the return flight.

1.6 The aircraft

1.6.1 General

THE AIRCRAFT	
Manufacturer	British Aerospace
Type	BAe 146-200
Serial number	E2048
Year of manufacture	1985
Gross weight	Maximum takeoff weight 40,596 kg, actual landing weight 33,418 kg
Center of gravity	Within allowable limits (C/G at landing 35,2 % MAC)
Total flight hours	20,336 hours
Number of cycles	20,246
Number of cycles since latest periodic check	829
Fuel uplifted prior to the event	9,362 kg JET A1

ENGINES				
Engine manufacturer	Lycoming			
Engine model	ALF 502R-5			
Number of engines	4			
Engine	Nr 1	Nr 2	Nr 3	Nr 4
Total operating hours	30,107	18,104	20,854	18,702
Total cycles	38,000	17,817	20,205	18,609
Cycles after overhaul	667	4,499	2,894	4,495

The aircraft had a Certificate of Airworthiness valid until the 26th of February 2004.

1.6.2 Wheel brake system

The aircraft type is equipped with hydraulic wheel brakes that have an Anti Skid System. The system is activated in connection with takeoff when the speed exceeds 15 knots and is deactivated during landing when the speed is reduced to under 30 knots.

The aircraft is not equipped with an Auto Braking System (automatic wheel braking) or with an Engine Reverse System (engine reverse thrust).

1.7 Meteorological information

A deep low-pressure area over the Norwegian Sea, preceded by snowfall and strong southerly winds, was moving in over northernmost Scandinavia.

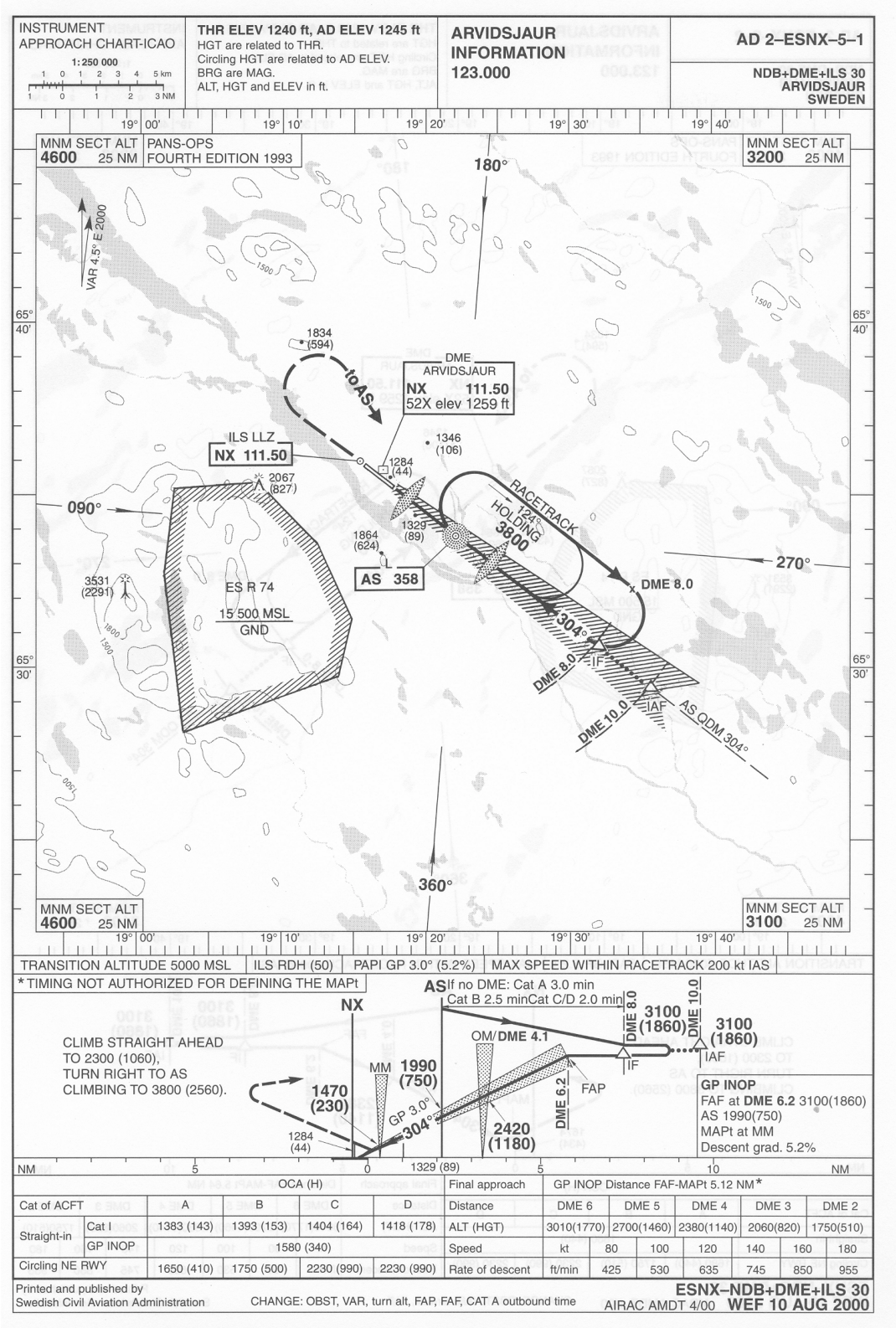
According to SMHI's analysis the following weather prevailed in the area at 13:20 hours: wind 180°/15 knots with gusts from 25–30 knots, visibility 5–10 km in light snow, clouds 8/8 with the ceiling at approximately 1,500 feet, temperature/ dew point –3/–6 °C, QNH 963 hPa.

During the final weather report prior to landing, which the crew received a little more than two and one-half minutes prior to touchdown on the runway, the wind was stated to be 180°/11 knots, gusts to 16 knots.

According to the aircrew and ground personnel, the wind and snowfall caused heavy snowdrifts across the runway.

1.8 Aids to navigation

Runway 30 at Arvidsjaur airport is equipped with NDB, ILS and DME as depicted on the approach plate below. Runway 12 is equipped with NDB and DME. The airport has AFIS service. The aircraft was equipped for instrument flight.



1.9 Radio Communications

Standard radio communications took place between Arvidsjaur AFIS and the pilots. (Appendix 1.)

1.10 Aerodrome information

1.10.1 General

The airport has a 2,000 meter long and 45 meter wide asphalt runway, situated on the magnetic headings of 124/304 degrees. Threshold height above sea level for runway 12 and for runway 30 is 1,245 feet (379 m) and 1,240 feet (378 m) respectively. A few hours prior to the incident the runway had been cleared of snow and sanded.

1.10.2 Measured braking action

The runway braking action was measured wit the assistance of a SAAB Friction Tester prior to and after the aircraft's landing. On both occasions the friction tester vehicle was driven along the entire length of the runway and back again at a distance of 5 to 10 meters from the runway centerline. A compilation of the measurement record from the four runs along the runway has been accomplished. (Appendix 2.)

Below is a summary of the recorded mean values for the respective runway sections, where section C represents the beginning of runway 30 and section A represents the end of runway 30.

Time	Section A	Section B	Section C	Note
12:45-12:46	49	49	48	33 min. before landing
13:46-13:47	48	49	50	28 min. after landing

During the test runs, the presence of ice patches on the runway was noted. The majority of these were located near the runway centerline in section A. The picture below was taken from the runway end shortly after the incident.

1.10.3 Definition of braking action

During measurement of a runway's braking action the nomenclature below is utilized;

Definition	Braking action
Good	40 and higher
Good to Medium	36 to 39
Medium	30 to 35
Medium to Poor	26 to 29
Poor	25 or lower

Note: Braking action is sometimes stated as a decimal value, that is, 40 corresponds to 0.40 μ etc. (μ = the friction coefficient).

1.11 Flight and voice recorders

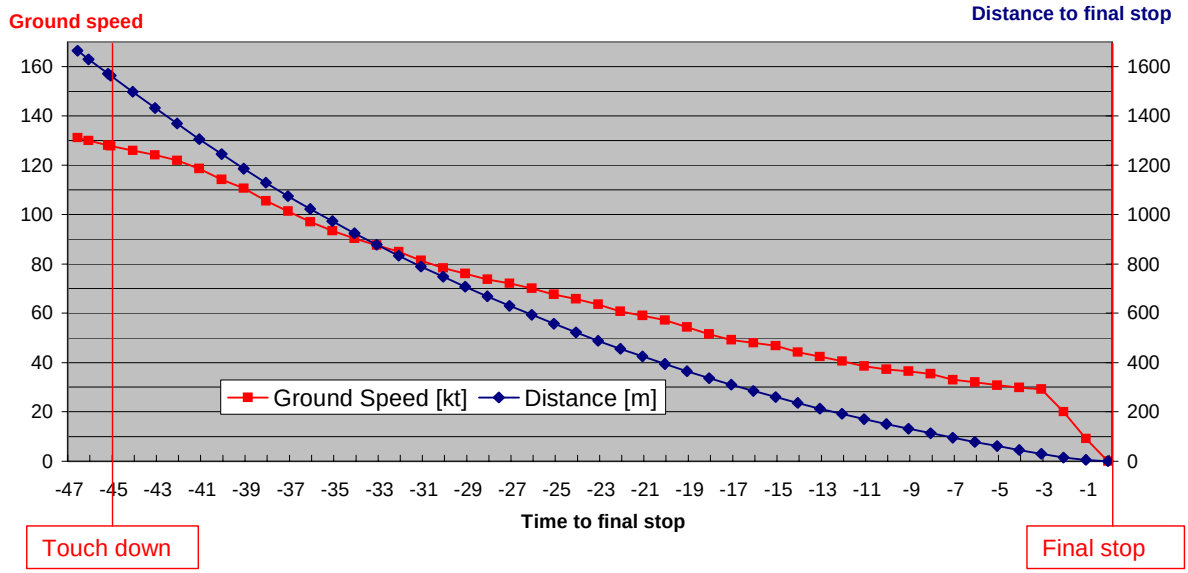
1.11.1 Flight recorders (FDR)

Subsequent to the incident the aircraft flight recorder was sent to the AAIB in England for deciphering. All of the relevant channels were recorded with good accuracy, with the exception of the registered IAS, which shows a registration of 20–30 knots too high, and the recorded pressure altitude, which depicts a value approximately 900 feet to high. The relevant parameters pertaining to the landing are presented in diagram form in Appendices 3A and 3B.

By means of the data registration, it can be determined that the landing was smooth and that the final touchdown on the runway took place approximately 45 seconds prior to the final stop. Less than three seconds after touchdown the Lift Spoilers[2] were completely deployed and after 9 more seconds the engine thrust was reduced from Flight Idle[3] to Ground Idle[4].

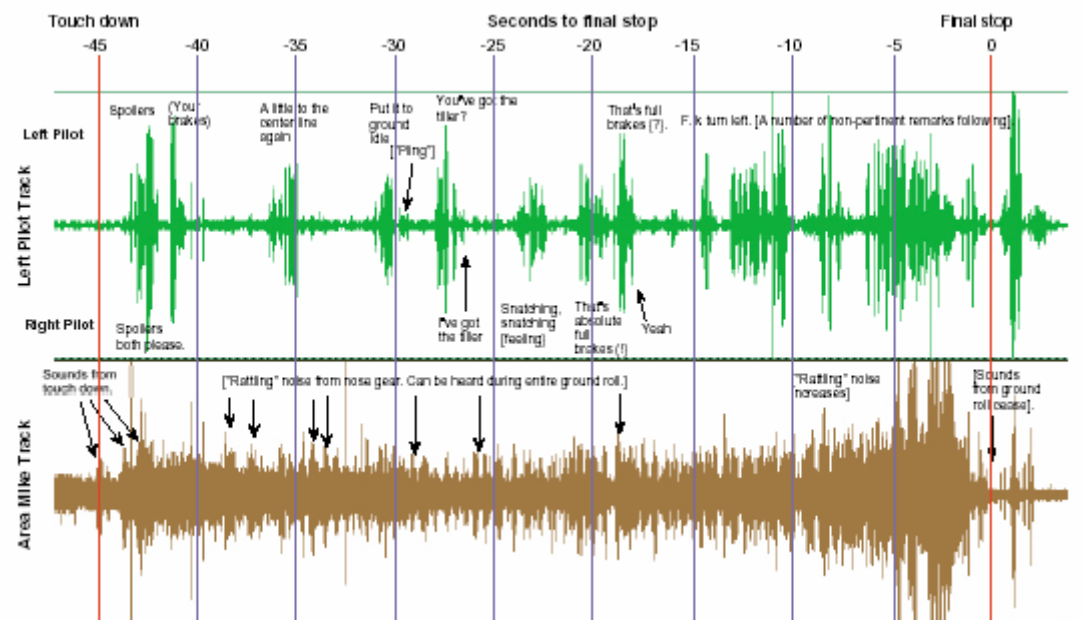
Based on recorded accelerometer data (NORM G and LONG G) the GS of the aircraft at touchdown has been calculated to have been between 125 and 130 knots (232–241 km/h). Using this same basic data, a touchdown point along the runway can be calculated which coincides well with that which was measured by the ground personnel. The diagram below depicts GS and the distance to the final stop of the aircraft as a function of time.

[2] The Lift Spoilers function is to decrease the aerodynamic lift of the wings after touchdown
[3] Flight Idle = Minimum thrust airborn
[4] Ground Idle = Minimum thrust on the ground, less than flight idle



1.11.2 *Cockpit voice recorder (CVR)*

After the incident the aircraft cockpit voice recorder was sent to the AAIB in England for transcription. Sounds and conversations in the cockpit during the entire approach have been recorded with good quality from 12:47 hours. A transcript of the recorded sound has been compiled (Appendix 1.). From the touchdown and rollout on the runway, an illustration has been produced based on a time-amplitude diagram of the CVR sound with the pilots' communications inserted - see below.



1.12 Incident site and the aircraft

1.12.1 Incident site

The touchdown point of the aircraft, determined by the ground personnel, was 475 meters down runway 30 from the runway threshold. The aircraft collided with a runway 12 threshold light and thereafter continued out onto a level snow-covered surface along the extended centerline of the runway, where it came to a stop in an approximately 50 centimeter deep snow bank, 83 meters from the runway (12) threshold, measured from the main landing gear.

1.12.2 The aircraft

Limited aircraft damage was caused to, among other things, the nose gear doors and two antennas.

1.13 Medical information

Nothing has been found that would indicate that the physical or mental condition of the pilots was impaired prior to or during the flight.

1.14 Fire

There was no fire.

1.15 Survival aspects

Those on board were not subjected to any abnormal g-forces and no personal injuries ensued.

1.16 Tests and research

1.16.1 Technical investigation of the aircraft

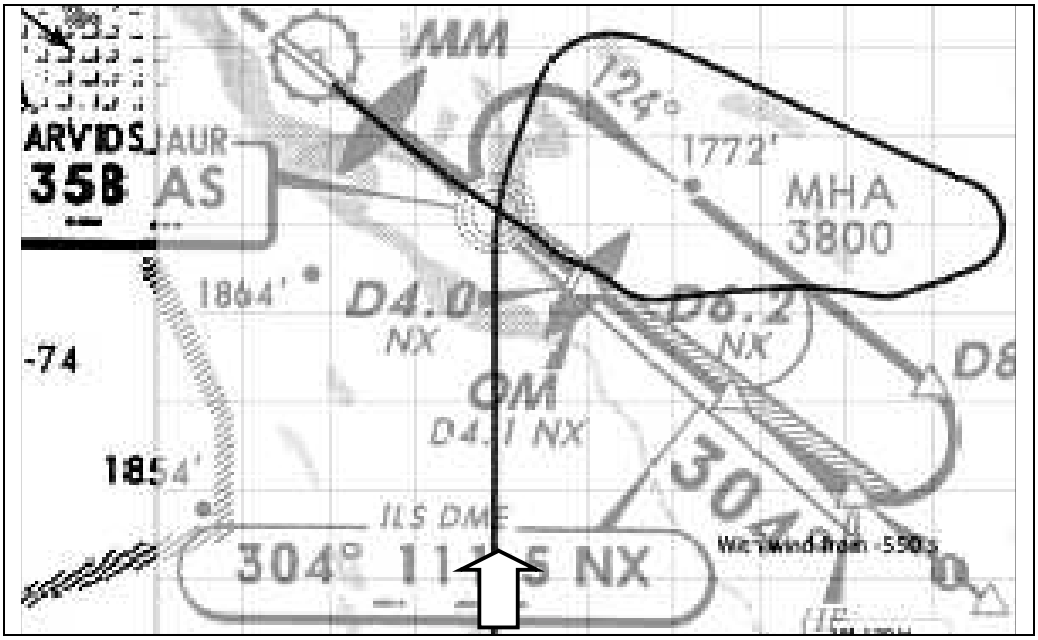
Subsequent to the incident a technical investigation and functional check of the aircraft wheel brake system was accomplished. No fault or abnormality could be established.

1.16.2 Quality control of braking action measurement equipment

After the incident, at the request of SHK, the friction test vehicle that was used has been inspected and calibrated. Comparable test measurements have been accomplished with another SAAB Friction Tester. The test vehicle utilized fulfilled the applicable calibration requirements and there is nothing that would indicate that any technical fault existed which could have influenced the test results.

1.16.3 The instrument approach

Based on FDR data and estimated winds in the area, an approximate approach path has been compiled and superimposed on the actual instrument approach chart shown below.



1.17 Organizational and management information

1.17.1 General

The company Flightline Ltd. has its headquarters at Southend Airport, Essex in England and conducts scheduled and non-scheduled passenger flights. The flight under investigation was undertaken as a charter flight on behalf of the German airline Lufthansa.

Prior to initiating operations at Arvidsjaur airport, representatives from the company performed an inspection (Risk Assessment) of the airport and produced a special information page, ”Route/Aerodrome Info”, with, among other things, security information about the airport, which was distributed to the crews concerned. SHK has not found any specific warning or instruction concerning landing with a tailwind component on a contaminated runway within these instructions or within any other of the company’s instructions to their pilots (see 1.18.1).

Prior to the incident, the company had conducted several flights to Arvidsjaur on behalf of Lufthansa and the pilots considered themselves very familiar with the airport.

1.17.2 Approach routines/data

According to the company's SOP, it is a requirement that the aircraft is established both vertically and horizontally prior to passing a height of 500 feet, in order to complete an ILS landing.

The Vref for the landing in question was 114 knots, as calculated by the crew. According to the SOP, the airspeed during approach shall be increased by 7 knots if icing conditions exist. The airspeed at touchdown is normally 7 knots lower than the airspeed over the runway threshold.

According the aircraft manufacturer's AFM, with a landing weight of 33,418 kg and 30 degrees of flaps, the Vref is 112 knots. In addition it is stated that normal landing speed (Basic Approach Speed) shall be Vref + 5 knots. During risk for icing conditions the landing speed shall be increased by 7 knots, which in the case at hand means a recommended landing speed of Vref + 12 knots. If icing conditions exist it is prescribed that certain portions of the aircraft shall be inspected concerning the presence of ice prior to initiation of final approach for landing.

1.17.3 Procedure after touchdown

After touchdown on the runway, according to valid routines, the aircraft Lift Spoilers shall be deployed and the engine thrust reduced from Flight Idle to Ground Idle. A delay of this thrust reduction with 15 seconds results in, according to the aircraft manufacturer, the stopping distance being increased by approximately 92 feet (28 meters) if the runway is covered by dry snow and by 198 feet (60 meters) if the runway is covered by wet ice.

1.18 Additional information

1.18.1 BAe MOM

According to the BAe MOM, section 9, a runway is defined as being contaminated if it is partially covered with water, slush or snow to a depth of more than 3 mm. With the actual landing weight, the calculated stopping distance, according to Bae MOM, section 9, is approximately 1,050 meters with optimum braking with the braking coefficients 49, 49, and 48 in calm winds.

1.18.2 JAR-OPS 1

In JAR-OPS 1.520 there are valid regulations concerning landing on contaminated runways. Based on these the aircraft manufacturer has produced diagrams concerning landing restrictions with respect to landing weight and tailwind component during operation on contaminated runways.; "Regulated Landing Weight on Contaminated Runways to JAR-OPS Requirements" (Appendices 4A and 4B).

– From the diagram for "CONTAMINATED – COMPACTED SNOW" (Appendix 4A) it is clear that landing with a tailwind component of more than approximately 7.5 knots is not allowed on a runway with compacted snow if the landing weight is 33,418 kg (actual) or higher.

– From the diagram for "CONTAMINATED – DRY OR WET SNOW" (Appendix 4B) it is evident that a landing with a tailwind component of more than 5 knots is not allowed on a runway with dry or wet snow if the landing weight exceeds 28,000 kg.

1.18.3 Analysis of retardation data

For the landing under investigation, BAe has calculated the theoretical stopping distance with different braking actions and the true braking action that corresponds to the actual retardation according to the FDR (Appendix 5). From the

diagram it can be determined that the retardation corresponds to an average braking action of 05 (0.05 μ).

1.18.4 Measurement and reporting of braking action

The difficulty in obtaining a representative value of an aircraft's possibility to decelerate on a contaminated runway by the use of wheel braking through measurement of the runway braking action is well known. Several factors can contribute to the fact that the actual braking action deviates considerably from that, which is measured and reported.
Examples of such factors are:
– that the measurement equipment is not correctly maintained and calibrated,
– that the measurement is not performed with the correct speed,
– that the measurement is not done along a path that is representative for the runway in general and
– that the braking action has time to change before the aircraft lands.

This problem has been addressed in, among others, two earlier reports published by SHK (C 1997:36 and RL 2000:41) and has brought about the following four recommendations to the Swedish Civil Aviation Administration:

"The Civil Aviation Administration is recommended to:

- place similar and specified demands on the maintenance and calibration of equipment for the measurement of runway braking action that are placed upon measurement instrumentation and tools which are used in the maintenance of aircraft and aviation materiel. *(C 1997:36 R1)*
- consider the requirement that the protocol of performed and reported measurements be signed by the person who performed the measurement. *(C 1997:36 R2)*
- complement existing instructions for measurement of braking action concerning measurements taken during snowfall with continuous snow removal *(RL 2000:41 R1)*
- introduce the routine that, during precipitation and risk of deterioration of the runway braking action, in connection with reporting runway braking action also report the time of the measurement *(RL 2000:41 R2)*."

2 ANALYSIS

2.1 Prerequisites

Approximately 25 minutes prior to the landing, when the pilots contacted Arvidsjaur AFIS, they were informed that the wind at the airport was 190°/11 knots with gusts up to 21 knots. Already then it was clear to them that a landing on runway 30 would entail a crosswind landing with a tailwind component. About ten minutes later it was reported that the wind had increased to 13 knots with gusts up to 22 knots. It was further reported that there were ice patches on the runway and that the measured breaking coefficients were 49, 49, 48.

As stated in paragraph 1.18.2 there are restrictions for the aircraft type concerning landing on contaminated runways with respect to landing weight and tailwind component, regardless of what braking action has been measured. With the above stated wind information the tailwind component on runway 30 would have been 4.5 to 7.5 knots, which means that landing on that runway was hardly

allowed, weather the runway condition in ”Regulated Landing Weight on Contaminated Runways to JAR-OPS Requirements” should be defined as ”CONTAMINATED – DRY or WET SNOW” or as ”CONTAMINATED – COMPACTED SNOW”.

Within the airline’s basic operational data, SHK has not found any instruction or teaching aids which should be used by pilots, in order to ensure that the above mentioned restrictions are adhered to, which constitutes a deficiency in the company’s operational routines.

If the pilots had had access to such information or aids, they would possibly have been more aware of the stated limitations and more observant that the landing might become problematic. It is also possible that they then had chosen to land on runway 12 instead, an alternative that may have been more suitable under the prevailing conditions.

2.2 The approach

It was a deficiency in the pilots’ planning of the landing that they did not concur on how the approach should be performed in adequate time prior to the approach, during a so-called approach and landing briefing. This caused the first officer to be forced to re-plan the approach at a late stage in the flight, when the aircraft had descended to an altitude of approximately 3,000 feet.

Instead of as he had planned, turning east and subsequently joining the ILS straight-in to runway 30 after a left turn, he was now suddenly forced to rethink and instead perform a full procedure turn approach via the initial approach beacon ”AS”. This caused the later portion of the approach to become forced, which possibly contributed to the fact that the pilot did not correct sufficiently for the strong crosswind, with the result that the approach path deviated considerably from the prescribed procedure.

It is evident from FDR data that the runway 30 localizer was initially joined at a late stage and only a few seconds before the aircraft passed the OM, just over three NM from the runway (See diagram in section 1.16.3). At this time the aircraft was above the glide path and the pilots considered abandoning the landing and performing a new approach. However everything would indicate that they succeeded in establishing the aircraft, both on the glide slope and on the localizer, before it passed 500 feet, which according to the company’s internal regulations is a demand in order to be able to continue the approach to landing.

Vref for the landing under investigation had been calculated to be 114 knots. In accordance with valid routines, the pilots had added 7 knots to Vref with respect to the risk of icing, which meant that the indicated speed (IAS) of the aircraft should have been approximately 121 knots during passage of the runway threshold. With compensation made for the airport’s altitude above sea level, this equates to an actual speed (TAS) of 126 knots. The final wind check reported prior to the landing was 180°/11 knots, which means that GS over the threshold should have been approximately 132 knots. As the normal speed reduction prior to touchdown is around 7 knots, it is therefore reasonable to assume that the touchdown speed was approximately 125 knots (GS).

There is no reliable registration of the IAS, however according to the calculation of GS that was accomplished based on registered g-forces, the GS was 125–130 knots at touchdown, which is well in accordance with the above assumption. This, in combination with the fact that the Vref used was 2 knots higher than prescribed, would indicate that the touchdown speed was somewhat too high in order to achieve the shortest possible stopping distance. On the other hand, at the time there was a prevailing gusty wind, which may warrant the landing taking place with a slight overspeed in order to gain increased margin to stall.

2.3 The landing

A runway excursion is always serious from the standpoint of flight safety, even if, as in the case at hand, no personal injuries resulted and the material damage was limited.

The investigation has not lead to any single explanation as to why the pilots did not feel as if the aircraft decelerated normally when they applied the brakes and why they were not successful in bringing the aircraft to a stop on the runway.

The technical investigation of the aircraft's wheel brake system has not revealed any fault or abnormality. That a momentary fault arose during the landing can of course not be completely ruled-out, however it would seem unlikely. With the braking action that had been reported to the aircraft prior to the landing, a normal braking to a stop should have been possible. The equipment and methods that had been used to determine the braking action on the runway fulfilled applicable requirements.

As mentioned earlier the landing conditions were difficult, with a gusty quartering tailwind on a runway that was contaminated with bands of snow and patches of ice. This however, does not seem to have induced any special measures on the part of the pilots before the landing. Instead of attempting to firmly set the aircraft down early on the runway and apply maximum braking immediately after touchdown, the aircraft was set down relatively a long way down the runway, after a normal flare.

It is likely that the incident was caused by several contributory factors.

- At touchdown the airspeed was somewhat too high and 474 meters (approximately 25%) of the runway length had already been utilized.
- Initially wheel braking was applied moderately which used-up additional runway length.
- The reduction of engine thrust first took place 12 seconds after touchdown, which according to BAe could have increased the stopping distance by 30–60 meters.

Also, after touchdown, the aircraft may have been affected by a strong quartering tailwind gust that temporarily increased the tailwind component during the roll-out and thus diminished the retardation and increased the stopping distance.

Contributing to the fact that the pilots did not anticipate any problems with the landing may have been that they considered the runway as being long and that they unconditionally trusted the braking action that had been reported.

If the braking action actually had been 49, 49, 48, the aircraft should have been able to be stopped on the runway remaining, despite the above mentioned factors. However, the braking action has been measured 33 minutes prior to the landing. As can be seen in the measurement graphs in Appendix 3, the runway braking action on the last third of runway 30 was lower, but above all more uneven, during the measurement that was accomplished 28 minutes after the incident. The reason for this is probably, that for the duration of time between the measurements it was snowing and very windy, which may have caused the development of new bands of snow across the runway. There are therefore a great deal of indications that the actual braking action along the path which the aircraft took, was worse than that which had been reported. This is reinforced by the retardation analysis performed by BAe, accounted for in section 1.18.3, where the actual braking action, – with the assumption that the pilots had used optimum braking –, should have been only 05 (0.05 μ).

Furthermore it is possible that the bands of snow and the patches of ice along the runway might have caused the aircraft's Anti Skid System to become momentarily "out of sync with the runway surface". This making the effect of these bands

and patches greater than what would be the case, considering their total area on the runway. The experience of the pilots that the braking effect at the end of the runway was very low, despite that they both applied full braking pressure, can be an indication that this did take place.

2.4 Retardation capability with the assistance of wheel braking

In addition to the technical problems of measurement which can arise during the measurement and reporting of braking action according to section 1.18.4, there are several things that would indicate that there are also other, as yet unsurveyed factors, which influence the correlation between measured braking action and the actual ability of the aircraft to decelerate by means of wheel braking. In other words, the braking action is not always representative of the actual braking capability of the aircraft. This is a subject that has been given international attention as well.
Examples of such factors could be:

- Aircraft type/aircraft weight
- Wheel brake system
- Tire type/tire condition/tire pressure
- Temperature on the runway
- Outside air temperature
- Atmospheric pressure and humidity
- "Interference" between Anti Skid systems and variations in the braking action
- Etc.

In order to increase safety during takeoff and landing on contaminated runways, practical means of assistance should be developed for the evaluation of such factors; to be applied operationally as a complement to the present method of determining braking action. Therefore SHK is of the opinion that the need exists for further research, in order to gain increased knowledge within this area.

It is also important that air traffic controllers as well as pilots are aware of the deficiencies in the present system and do not consider measured and reported braking action values as absolute, but as reference values to weigh against other factors prior to landing. Also, the possibility for an air traffic controller to report and for a pilot to request complimentary information concerning the runway condition shall always be utilized when the need arises. In case of uncertainty about the runway condition, a pilot also always has the possibility to request a new measurement of the braking action prior to making the decision about landing.

3 CONCLUSIONS

3.1 Findings

a) The pilots were qualified to perform the flight.

b) The aircraft had a valid Certificate of Airworthiness.

c) The landing prerequisites were marginal according to JAR-OPS 1 and BAe MOM, Part 9.

d) Deficiencies were found to exist in the aviation company's operational routines.

e) Deficiencies were found to exist in the pilots' preparations prior to the landing.

f) The instrument approach to runway 30 deviated from the specified procedure.

g) The aircraft was established on the runway 30 ILS when it passed 500 feet.

h) The landing took place with a tailwind component.

i) The touchdown speed was somewhat too high to be able to achieve optimal stopping distance.

j) The touchdown occurred 475 meters down the runway (approximately 25% of the runway length).

k) The initial wheel braking was applied moderately.

l) The reduction of engine thrust after touchdown was accomplished approximately 12 seconds after the touchdown.

m) The actual braking action was probably worse than that which had been reported.

n) An aircraft's actual braking capability using wheel braking, in relation to the measured braking action, is probably affected by factors that have not yet been surveyed.

o) No technical fault, which could have influenced the incident, has been found on the aircraft or on the equipment which was used for measuring of the runway's braking action.

3.2 Causes of the incident

The incident was probably caused by the following contributory factors:

- The landing prerequisites were marginal.
- The touchdown speed was somewhat too high.
- The touchdown took place far down the runway.
- The initial wheel braking was applied moderately.
- The reduction of engine thrust after touchdown was delayed.
- The aircraft may have been affected after touchdown by strong wind gusts that temporarily increased the tailwind component.
- The actual braking action was probably worse than that which had been reported.

4 RECOMMENDATIONS

The Civil Aviation Administration is recommended to – through the international cooperation of aviation authorities – work for that research is initiated on the mechanisms involved during wheel braking of commercial aircraft on contaminated runways, with the intention of obtaining more reliable information concerning an aircraft's actual braking ability in relation to the measured braking action. *(RL 2003:08e R1)*

Appendix 1

LH5184, G-FLTA, CVR-recording and radio traffic from 2002-02-22

Abbreviations

UTC:	Co-ordinated Universal Time according to Arvidsjaur ATC.
Time:	Time to the final stop of the aircraft
Frm:	From, Sound source.
SDL	Sundsvall ATC.
AFIS	Arvidsjaur AFIS.
LP	Aircraft commander
RP	First officer
Eng	Flight mechanic in the cockpit.
Lloyd	Aero Lloyd 9750
N:	Note
#	Radio transmission.

Information:
[Brackets] indicate additional information.
(Parentheses) indicate uncertain information.
?? indicates undescernable information.
? indicates a question or uncertain interpretation of sound.

UTC	Time	Frm	N	Information
		AFIS	#	5184 Arvidsjaur, good day
11:47		LP?	#	(We are still well 15) minutes to go, so we are looking for your latest weather report, please.
		AFIS	#	LH 5184 we have wind 190 degrees, 11 knots, max 21 ?? visibility 10 kilometers in light snow, overcast at 1400 ft, ?? [Recording volume reduced to zero for ca 2 sec-onds] 3, dew point –6, QNH 964, TL 65.
		LP?	#	OK, that's copied and QNH 964. Can you please say again the visibility.
		AFIS	#	Visibility 10 kilometer.
		LP?	#	Oh, thank you very much. (see you later, thanks).
	-1393			LH5184 standing by for descent.
	-1390			LH5185 descend to FL 100.
	-1386			Descending FL100, LH5184.
	-1061			LH5184, continue descent towards AS, Arvidsjaur QNH 963, TL is 65, and no traffic reported below controlled airspace.
	-1045			All right, that is understood, so we carry on towards AS, Arvidsjaur QNH 963, but we are initially just cleared FL100, is that confirmed, for the LH5184.
	-1033			LH5184, you may continue descent below FL100 on the QNH. It's uncontrolled airspace below and there is no traffic reported.

	-1023			Okay in this case we continue descent for the ?? approach to Arvidsjaur, for the LH5184, checked, thanks.
	-1017			LH58, correction 5184, you may also contact Arvidsjaur frequency 123.0
	-1009			Arvidsjaur 1230 LH5184, thank you very much goodbye
	-1005			Bye
11:57	-974	LP?	#	Arvidsjaur, good day again, the LH5184 out of FL140, descending down to 6000 ft initially, and we are 41 miles south of your airfield.
	-959	AFIS	#	LH 5184, Roger no reported traffic, report established runway 30, wind 190 degrees, 13 knots, max 22, QNH 963.
	-946	LP?	#	963 and we'll call, Lufthansa 5184.
	-939	AFIS	#	And LH 5184, we have sand on runway, ice patches, braking action 49, 49, 48.
11:58	-929	LP?	#	That's all we need, thank you very much, 5184.
	-685	LP		[Morse code from AS NDB]. Identified 1,
	-677	RP		The field says 356, makes a safety altitude 3100. [ADF indicates 356° to NDB AS]
	-673	LP		Yeah, what I do not understand is why do actually turn on heading 025 now?
	-668	RP		Well because I recon on the AS [NDB] is inside the marker, which is at the descent point.
	-661	LP		Well AS 358. Don't you wanna do a standard approach? [358 is the frequency for NDB AS]
	-654	RP		(Oh well, I suppose,) trying to get us straight on the centre line. If you want us to that, yeah, we'll do that. I misint…
	-649	LP		Well I don't mind, I mean..
	-646	RP		We will go towards the beacon. I will go outbound, yeah. Yeah, I suppose we ought to stick to it that way…. Right.
	-636	LP		[Sound from altitude alert] 3100.
	-631	RP		Yeah. Going up on north. Slowing down. Need some airbrake. (?? to sink.)
	-610	LP		So we have 360 towards the beacon there. There is just a mast you know, left to us, of 3531 feet.
	-603	RP		But we are coming in from the right angle for it, it'll be 3100.
	-598	LP		Yeah, all right.
	-595	RP		And the approach is flown from. Is it 3?….3, 31, (??.. flared). Let's go flap 18 please.
	-578	LP		Well already?
	-576	RP		Yeah. And we go out to 8D Right 7 miles to the beacon. [The outbound turning point is at distance 8].
	-563	LP		Put the airbrakes back in?
	-562	RP		Yeah, thanks.
	-561	LP		Welcome. You want to turn a little right.
	-556	RP		Yeah. (Should drop a little slightly). You'd think they had radar here wouldn't you.
	-494	RP		So we got an APU, we are all complete on that then. Coming to the beacon..
	-447	LP		Yeah it looks good.
	-443	RP		Take it across for about 20 seconds.

	-440	LP		8 miles it says.
	-439	RP		Yeah, no, (to give us space) on the downwind leg.
	-433	LP		Yeah OK, oki doki.
	-432	RP		And 31 is OK here. [3100 ft altitude]
	-427			[9 seconds of silence where CVR tape is cut for investigation playback. For exact comparison 9 seconds should be subtracted from CVR times below]
	-423	RP		Identify please.
	-420	LP		For the ILS?
	-420	RP		Yes please.
	-418	LP		[Morse code for NX – ILS, is heard].
	-417	RP		30 seconds, going right 124, winds from south...[Interrupted by AFIS].
	-414	AFIS	#	Lufthansa 5184 your distance?
	-411	LP	#	5184 is with you.
	-405	LP	#	We are just following the procedure turn now, going to 8 miles, before we turn onto final, LH 5184.
	-399	RP		I think he thought we were gonna do..
	-397	LP		Yeah well whatever
	-395	LP		Yeah I know, I know. It's where you had half a piece of navkit. That's out to 8 miles, maintain the height.
	-373	RP		He's probably as blind as we are in his tower.
	-370	LP		Indeed, indeed.
	-357	LP		La, la, la 5 minutes given. [Sound of switch – No smoking sign off/on to warn C/A]
	-348	RP		Downdrafts and updrafts around here.
	-318	RP		I was going to go out there and find it, but this is more official.
	-312	RP		A mile to the turn.
	-305	RP		And the descent starts at 6.2.
	-285	LP		ILS is identified on 1 and 2.
	-283	RP		Thanks.
	-273	LP		So we are now actually in icing conditions, we should add 7 knots to the speeds.
	-269	RP		(We add that to the Vref) [or "I will land at Vref"]
	-267	LP		Yeah you do that roughly, don't you.
	-266	RP		Yeah.
	-265	LP		All right.
	-252	RP		We need to go a little bit south at the moment.
	-220	LP		(Oh yes), still 15 degrees to go, aren't there.
	-217	?		(Yeh to take ??)
	-212	LP	#	Lufthansa 5184 is turning finals.
12:10	-207	AFIS	#	LH 5184, wind 180 degrees, 11 knots, max 16, runway free.
	-199	LP	#	That is copied 5184.
	-198	LP		Yeah you have 180, you won't make it….
	-196	RP		Yeah, this wind much stronger up here than I allowed for.
	-188	RP		Much stronger up here, we are making no impression at all.
	-182	LP		Why, it is 6 miles on the glideslope.
	-177	RP		Let's do a left turn back on, please.
	-173	LP		Right

	-170	LP		Where are you coming now? You wanna do a 360?
	-167	RP		Are you happy to go down.
	-166	LP		Yeah I am,
	-165	RP		OK let's go.
	-164	LP		There's the localizer.
	-161	LP		(If you now) turn around you make it.
	-159	RP		OK gear down please.
	-157	LP		Gear is coming down. [Sound of gear].
	-150	LP		And as long we are high on glide I mean it's all right.
	-147	RP		Yeah OK. [Two rings in background from Autopilot dis-connect].
	-144	LP		I give you the flaps?
	-143	RP		Yes please. And the landing check please.
	-141	LP		Coming shortly.
	-136			["Pling" - High pitch tone – Master Warning System. Probably Low Pressure warning in connection with Wing anti ice. Sound of several switches (for wing anti-ice?) in background].
	-126	RP		We are about well high. [Sound of altitude alert in back-ground].
	-118	RP		Give me height against range please.
	-116	LP		All right, we have 2600 we should be where we are.
	-116	RP		Oh there we are, there we are.
	-114	LP		You're gonna make it.
	-112	RP		More flap please.
	-111	LP		I give you all.
	-110	RP		Thanks.
	-107	LP		That wind is horrendous up there.
	-100	RP		A bit of airbrake please.
	-98	LP		Coming.
	-97	LP		So gear is down, altimeters we have done, brakes is checked, are they. I do that for you. They are checked on green. Are we cleared to land?
	-89	RP		Yes we are, but check.
	-88	LP		You are coming back on glide.
	-87	RP		(Check) please.
	-84	LP		Ah, lights, flaps done, go around is set and armed, the cabin is seated, checks are completed sir.
	-78	RP		Thank you.
	-77	LP		You are welcome.
	-66	LP	#	Confirm clear to land?
	-63			["Minimum, minimum" from aircraft system]
	-63	AFIS	#	Runway free
	-62	LP?	#	[Click]
	-61	RP		Airbrakes please.
	-59	LP		Airbrake.
	-45			[Sound from light touchdown. Could be from one main wheel].
	-44			[Ca 2 seconds with sound from heavier touchdown, and thereafter a rattling noise can be heard for the remain-der of the ground roll. Could be the other main wheel and then the nose wheel].

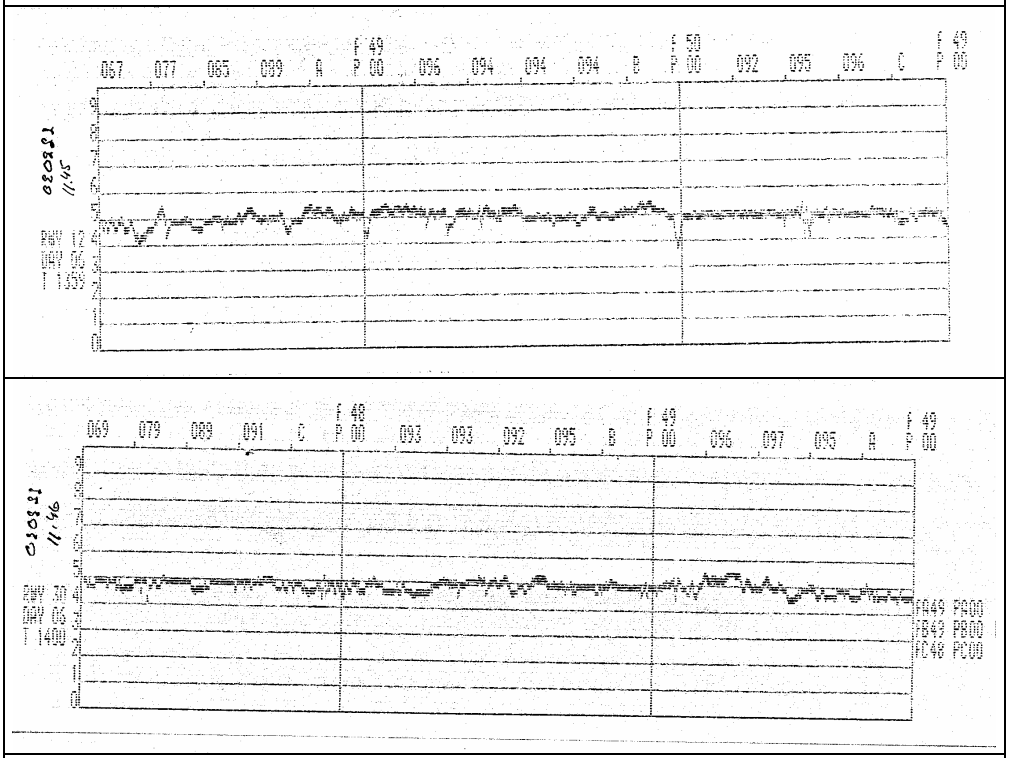
	-43	LP		Spoilers.
	-43	RP		Spoilers both please.
	-42	LP		(Your brakes).
	-36	LP		A little to the centreline again.
	-31	LP		Put it to ground idle.
	-29			["Pling" –High pitch tone in background – Master Warning – Engine anti-ice on?].
	-27	LP		You've got the tiller?
	-27	RP		I've got the tiller.
	-24	RP		Snatching, snatching (feeling). [or "snatching, snatching, feel it"]. [-Referring to Anti-skid system behaviour?]
	-21	RP		That's absolute full brakes!
	-19	LP		That's full brakes?
	-18	RP		Yeah.
	-16	LP		F..k turn left. [A number of non-pertinent remarks following].
	0			[Sounds from ground roll cease].
	5	Eng		We'd stopped in the end.
	7	LP		Cabin crew, normal operation, normal operation, normal operation [On public address].
	11	RP		?? to stop it.
	13	Eng		There was full pressure there.
	15	RP		Speed was OK wasn't it.
	17	LP		It was fine absolutely.
	21	LP		We shut it down. OK we just shut it down.
	27			[A series if "Pling" signals from engines being shut down].
	37	Eng		(Straight off the end of the runway)
12:13	38	LP	#	Tower it's the Lufthansa 5184.
	44	AFIS	#	Arvidsjaur.
	48	LP		We'll we, we are fine, aircraft is normal conditions, but we need assistance, please.
12:14	55	AFIS	#	OK (Lufthansa).
	56	LP	#	Thank you.
	61	LP		(So meine Damen und Herren die captain) ich hoffe es geht's allen gut, (wir sind über die Bahn rausgeschossen), der Grund dafür die braking Action, die Brems … war anders als uns gemeldet worden ist. War keine Chance etwas dagegen zu machen. Ich .. ist alles vorbereitet die Evakuhehrung findet statt (persönlich bitte ich ihn Entschuldigung). Aussteigen wird gleich per Treppen wenn es geht statt finden, melde ich gleich. [Passenger announcement in German].
	98	LP		Well that's my job then, thank you very much,
	104	LP	#	?? from tower again from the Lufthansa 5184
12:18	112	AFIS	#	5184 go ahead.

	115	LP	#	Well there was the braking action now, I wouldn't call it 49, I would call it very very very poor, none at all, basically the part where we touched down was fine at, starting at the, well second third of the runway, there was just nothing anymore whatsoever.
12:19	132	AFIS	#	OK.
	137	RP		So you were watching the pressure?
	138	Eng		I was watching all the way.
	140	RP		Well speed was OK at threshold.
	144	LP		I thought at the moment when the approach wasn't very nice, but you came back on glide, came back on speed, it was gusty, you touched it down with a positive touchdown. That's all we can ask for. You braked it fully. It was all right in the beginning, the you said you slow it down, then I thought, shall I put on power and begin a go-around, but then it was too late, it was too late, it would have made it worse, so sorry.
	166	RP		I was a little slow getting nose in but I don't think that made much difference.
	175	Eng		(You could feel the wheels locking)
	177	RP		??
	181	Eng		You could see it on the pressures as well.
	185			[Continued discussion about landing and with cabin attendants concerning passenger embarkation].
	238	RP		We had a stabilized approach from 500 feet and down, which is the requirement.
	364	RP		I thought we getting normal braking actions, 49 ??
	366	LP		Yeah, absolutely. Well it's all on the tape.
	370	RP		That's why I wouldn't land and smack the brakes to the floor cause 49 is fine
	376			[End of CVR recording]
12:36		LP	#	Tower from the LH 5184.
		AFIS	#	5184 Arvidsjaur, go ahead.
		LP	#	Have you actually made brake action test after the incident happened?
		AFIS	#	Yeah, we have 50, 50, 51.
		LP	#	(Thank you)
		?	#	[2 seconds of noise transmission]
		Lloyd	#	Good afternoon, Aero Lloyd 9750
12:37		AFIS	#	Aero Lloyd 9750 Arvidsjaur.

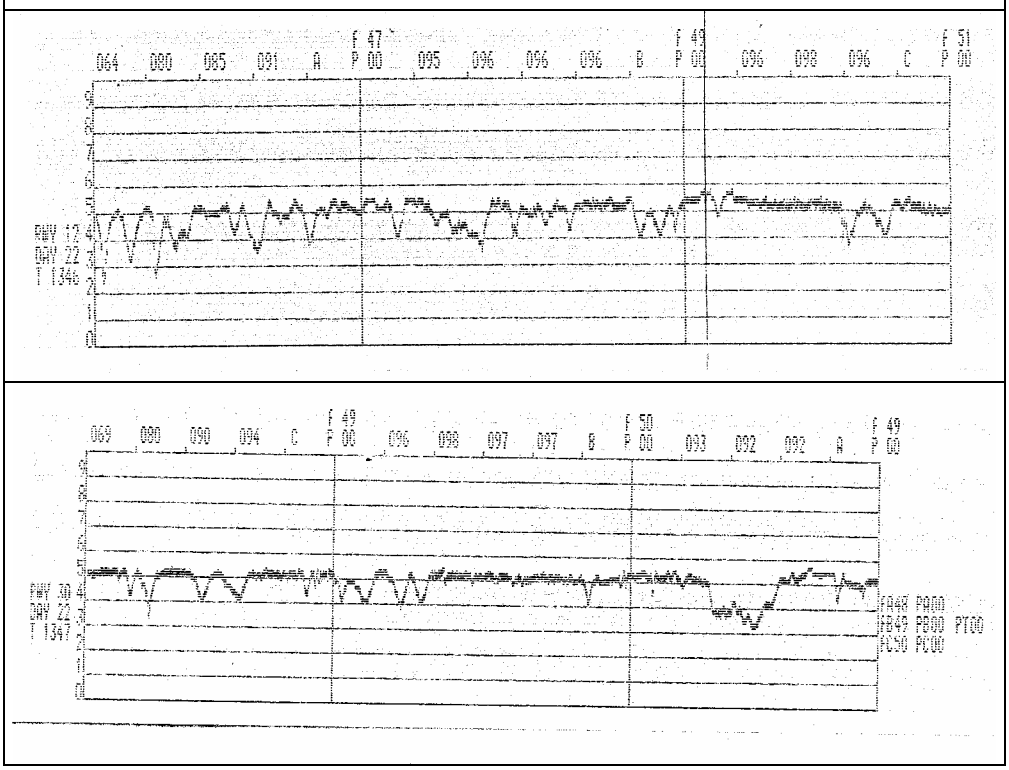
Appendix 2

Compliation of recording protocol from performed measurements of the braking action.

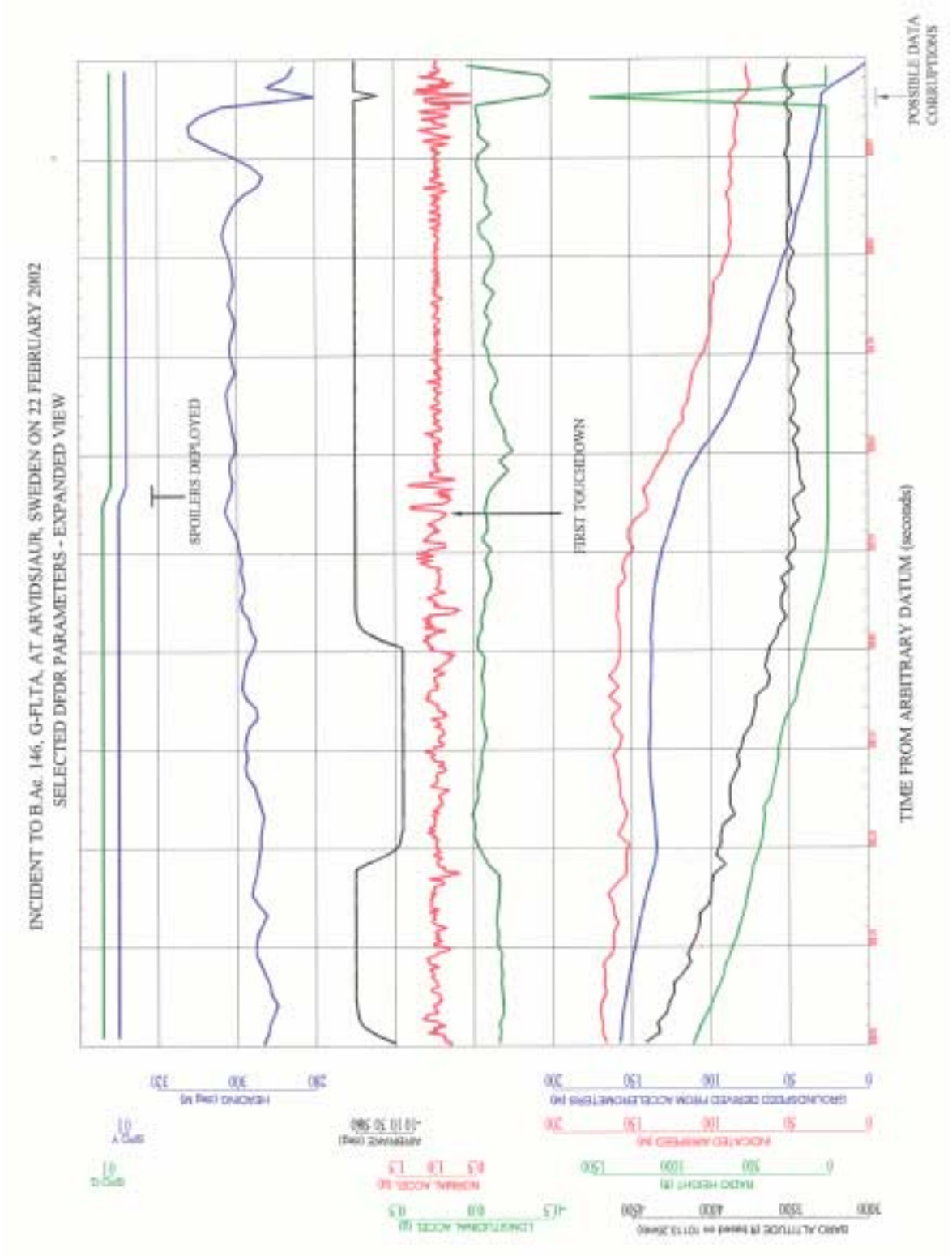
Recorded braking action 33 minutes prior to the aircraft's landning



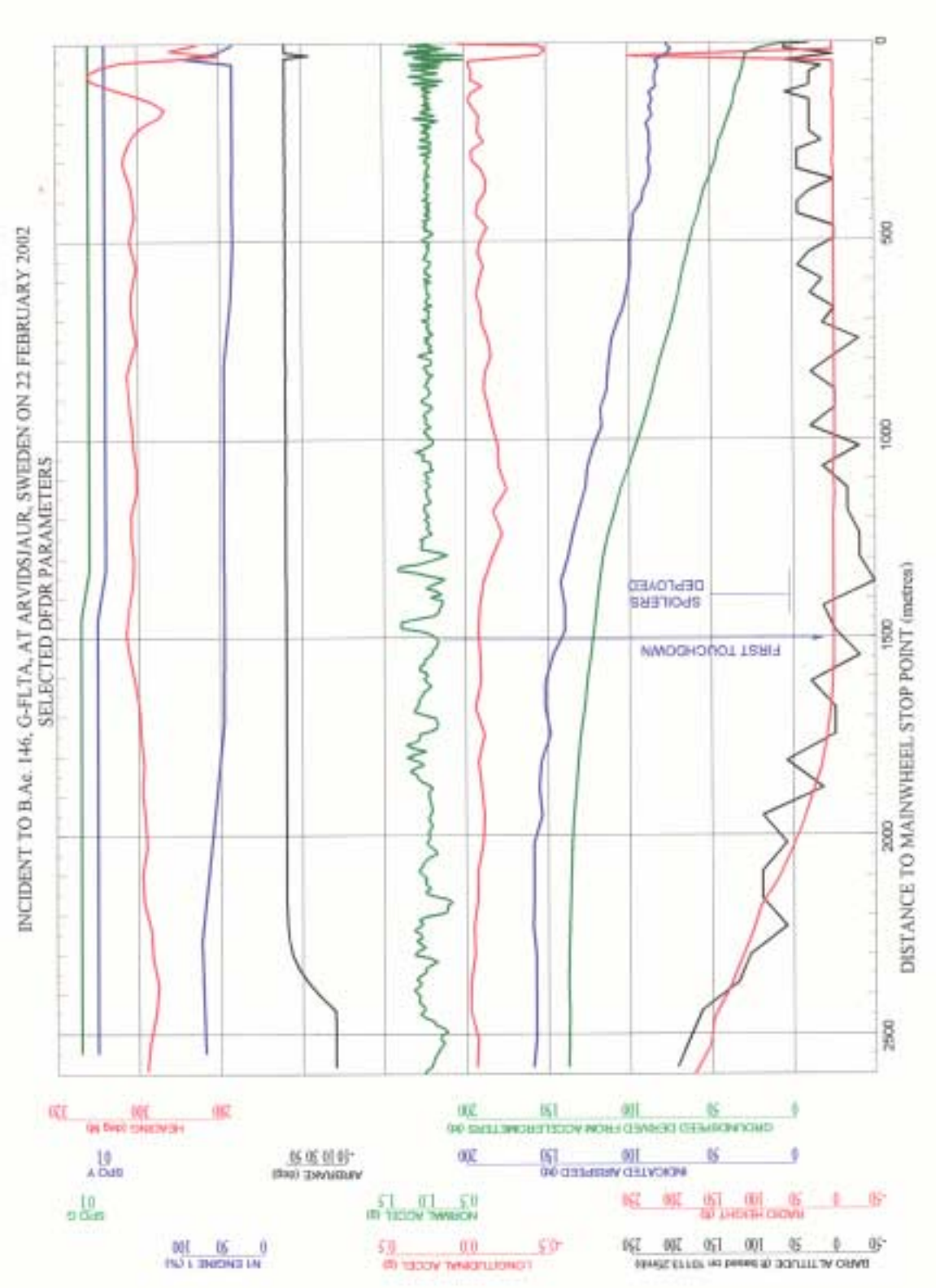
Recorded braking action 28 minutes after the aircraft's landning



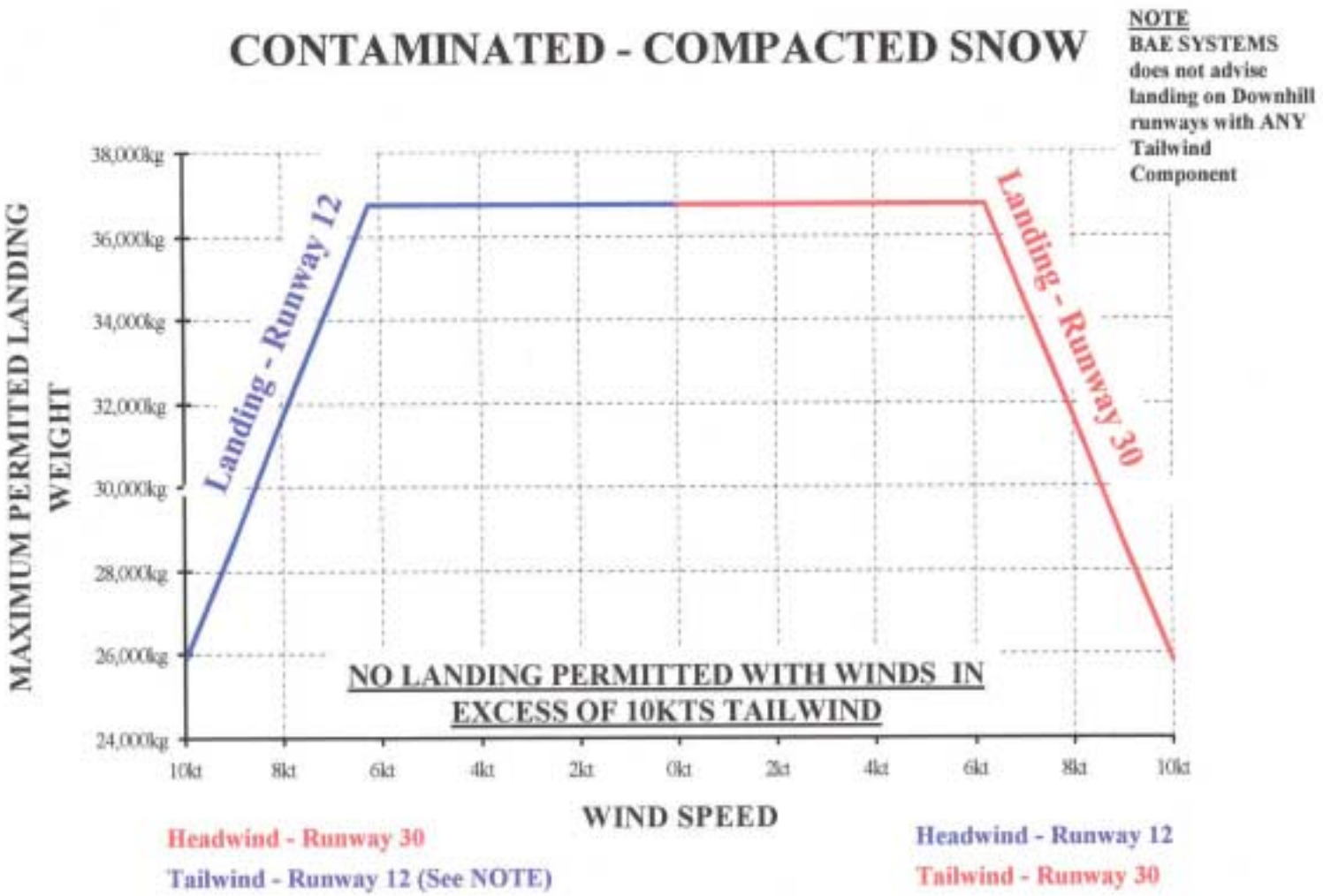
Appendix 3A


INCIDENT TO B.Ae. 146, G-FLTA, AT ARVIDSJAUR, SWEDEN ON 22 FEBRUARY 2002
SELECTED DFDR PARAMETERS - EXPANDED VIEW
SPOILERS DEPLOYED
FIRST TOUCHDOWN
POSSIBLE DATA CORRUPTIONS
TIME FROM ARBITRARY DATUM (seconds)

Appendix 3B

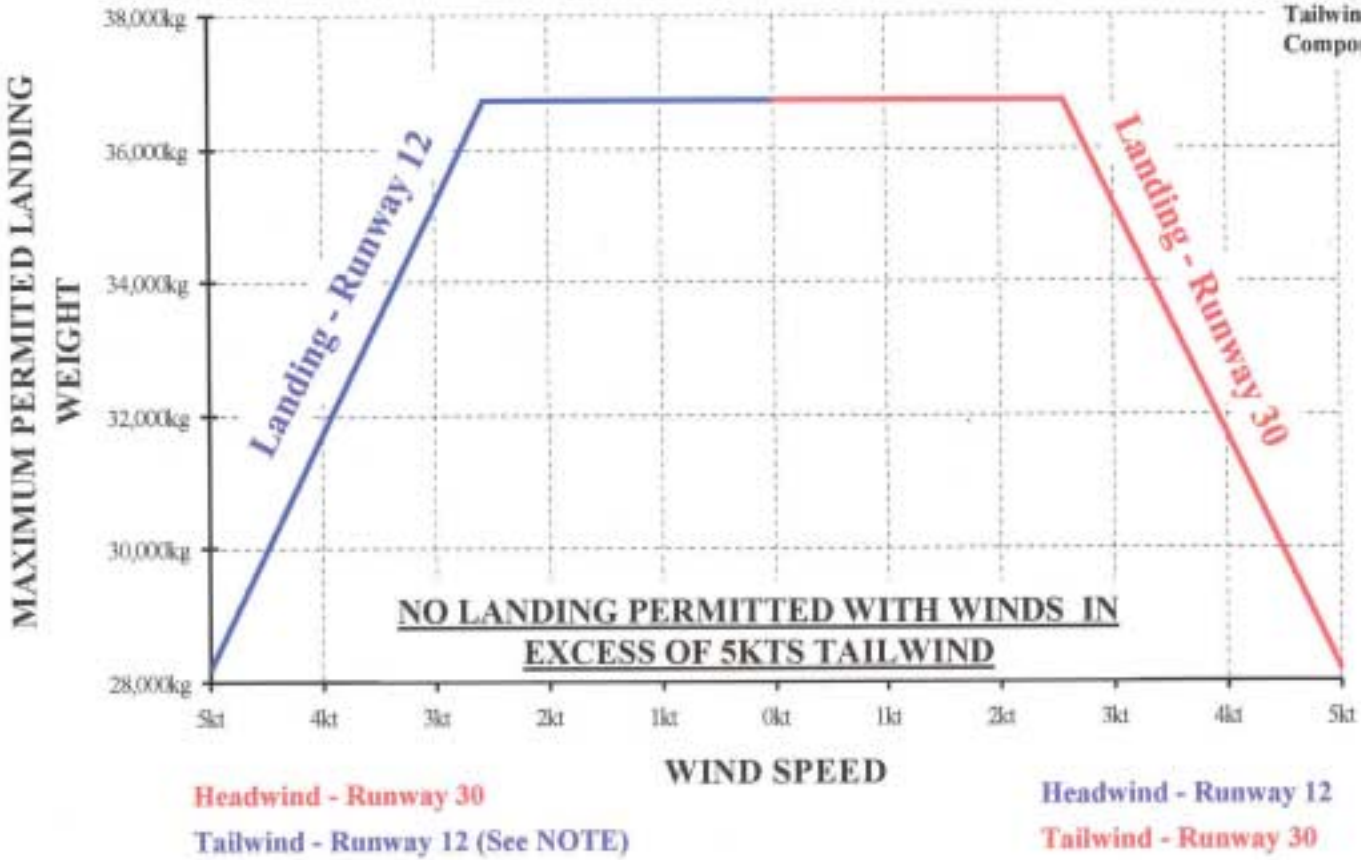

INCIDENT TO B.Ac. 146, G-FLTA, AT ARVIDSJAUR, SWEDEN ON 22 FEBRUARY 2002
SELECTED DFDR PARAMETERS
DISTANCE TO MAINWHEEL STOP POINT (metres)
0
500
1000
1500
2000
2500
SPOILERS DEPLOYED
FIRST TOUCHDOWN

BAe146-200 Regulated Landing Weights on Contaminated Runways to JAR-OPS Requirements

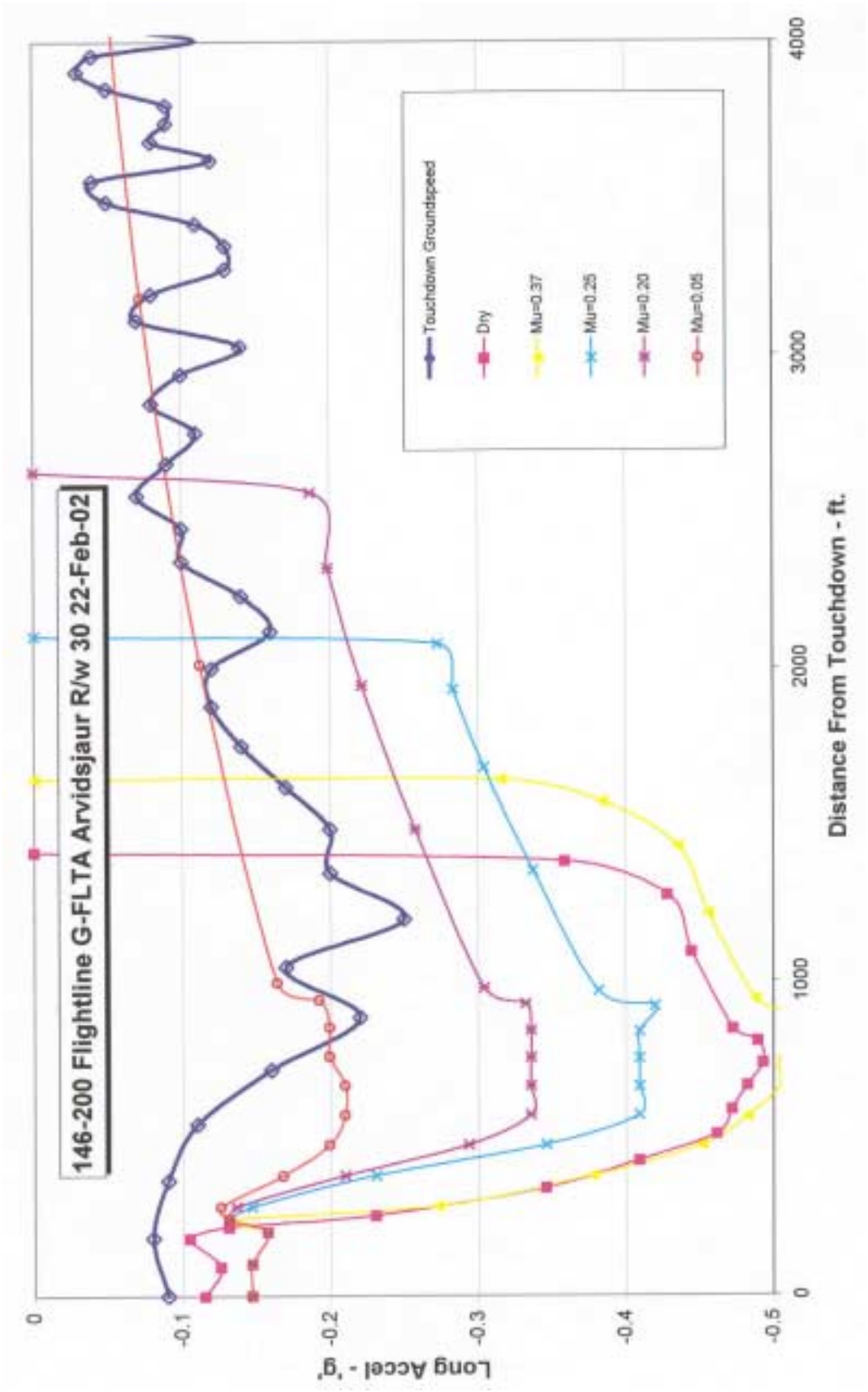


BAe146-200 Regulated Landing Weights on Contaminated Runways to JAR-OPS Requirements

CONTAMINATED - DRY or WET SNOW



Appendix 5


146-200 Flightline G-FLTA Arvidsjaur R/w 30 22-Feb-02
Touchdown Groundspeed
Dry
Mu=0.37
Mu=0.25
Mu=0.20
Mu=0.05
Long Accel - 'g'
0
-0.1
-0.2
-0.3
-0.4
-0.5
Distance From Touchdown - ft.
0
1000
2000
3000
4000