



Final report RL 2017:03e

Serious incident at Gällivare Airport on 6 April 2016 involving the aeroplane YR-FZA of the model F28 Mark 0100, operated by Carpatair.

File no. L-33/16

9 March 2017

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK's web site: www.havkom.se

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General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on 6 April 2016 that an incident involving one aircraft of the model Fokker F28 Mark 0100 with the registration YR-FZA had occurred at Gällivare airport in Norrbotten County, on the same day at 21:35 hrs.

The incident has been investigated by SHK represented by Mr Mikael Karanikas, Chairperson, Mr Nicolas Seger, Investigator in Charge, Mr Johan Nikolaou, Operations Investigator and Mr Ola Olsson, Technical Investigator.

The investigation team of SHK was assisted by Mr Christer Magnusson as a sound expert.

Mr Cristian Tecuceanu from the Civil Aviation Safety Investigation and Analysis Center (CIAS) has participated as accredited representative of Romania.

Mr Hans van Ruler from the Dutch Safety Board (DSB) has participated as accredited representative for the Netherlands. Mr Evert van Benthem, Fokker Service B.V. has participated as advisor to the Netherlands' accredited representative.

The investigation was followed by Mr Magnus Eneqvist, Ola Johansson and Bengt Holmqvist from the Swedish Transport Agency.

Ms Raluca-Maria Negoescu and Mr Alessandro Cometa from EASA have participated as advisor.

The following organisations have been notified: The International Civil Aviation Organisation (ICAO), the European Commission, the European Aviation Safety Agency (EASA), the Swedish Transport Agency (Transportstyrelsen) and the safety investigation authorities of Romania, Netherlands and UK.

Investigation material

Interviews have been conducted with the commander, the co-pilot, cabin crew and personnel at Gällivare Airport.

Information from CVR¹, DFDR² and recordings from Gällivare Airport have been recovered and analysed.

A meeting with stakeholders was held on 29 November 2016. At the meeting SHK presented the facts collected during the investigation, which were available at the time.

¹ CVR – Cockpit Voice Recorder.

² DFDR – Digital Flight Data Recorder.

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Aircraft:	
Registration, type	YR-FZA, F28
Model	Fokker F28 Mark 0100
Class, Airworthiness	Normal, Certificate of Airworthiness and valid Airworthiness Review Certificate (ARC) ³
Serial number	11395
Operator	Carpatair S.A.
Time of occurrence	06/04/2016, 21:35 hrs during darkness Note: All times are given in Swedish daylight saving time (UTC ⁴ + 2 hours)
Place	Gällivare Airport, Norrbotten County, (position 6708N 02047E, 1 027 feet above mean sea level)
Type of flight	Commercial Air Transport
Weather	According to METAR ⁵ : wind 030 degrees 8 knots, visibility 1 500 meters in snow and rain, vertical visibility 800 feet. temperature/dew point 0°/-0°C, QNH ⁶ 994 hPa
Runway conditions	Reported friction coefficients: 0.36, 0.34, 0.35, contamination 1 mm slush
Persons on board:	55
crew members including cabin crew	4
passengers	51
Injuries to persons	None
Damage to aircraft	Slightly damaged
Other damage	None
Commander:	
Age, licence	42 years, ATPL ⁷
Total flying hours	8 285 hours, of which 3 496 hours on type
Flying hours previous 90 days	216 hours, all on type
Number of landings previous 90 days	110
Co-pilot:	
Age, licence	24 years, CPL ⁸
Total flying hours	770 hours, of which 518 hours on type
Flying hours previous 90 days	228 hours, all on type
Number of landings previous 90 days	105

³ ARC - Airworthiness Review Certificate.

⁴ UTC – Coordinated Universal Time is a reference for the exact time anywhere in the world.

⁵ METAR – Meteorological Aerodrome Report.

⁶ QNH - Barometric pressure reduced to mean sea level.

⁷ ATPL - Airline Transport Pilot License.

⁸ CPL - Commercial Pilot License.

SUMMARY

The serious incident occurred during a scheduled flight from Arvidsjaur to Gällivare airport and involved an aeroplane of the model Fokker F28 Mark 0100 with the registration marks YR-FZA. The aircraft was operated by the Romanian operator Carpatair on behalf of the Swedish airline Nextjet.

During the instrument approach to runway 30 at Gällivare airport, which was performed in darkness with snow and rain, the runway threshold was crossed at approximately 50 feet with a recorded speed of 134 knots. After a hard landing in the touchdown zone with unchanged speed the aeroplane bounced and was displaced in yaw. Reported friction coefficients were 0.36, 0.34 and 0.35.

After the landing, which was performed with full flaps and extended speed brake, the lift dumpers on the wing's upper surface extended. According to interviews, maximum reverse was activated and the brakes were applied immediately after the displacement in yaw. Data from the recordings indicate that reverse rpm increased from low idle only 20 seconds after touchdown at a speed of about 50 knots. Engine reverse rpm then only reached 75 % and 65 %, while the maximum speed limitation is 95.5 %.

The aeroplane overran the end of the runway and came to a full stop on the runway strip. There were no injuries and the damage to the aeroplane was limited.

The serious incident was caused by the gradual decrease of the conditions for a safe landing, which was not perceived in due time.

Contributing factors:

- The airspeed did not decrease from 50 feet's height to touchdown.
- The reported friction coefficients were probably unreliable.
- The wheel brakes were probably not fully applied due to the initial yaw disturbance.
- The reverse rpm increased only 20 seconds after touchdown.

Safety recommendations

ICAO is recommended to:

- Work for the introduction of a generic Safe Landing concept including the flight phase from the runway threshold until full stop. (RL 2017:03 R1)

EASA is recommended to:

- Work for the introduction of a generic Safe Landing concept including the flight phase from the runway threshold until full stop. (RL 2017:03 R2)

The Swedish Transport Agency is recommended to:

- Work for the introduction of a generic Safe Landing concept including the flight phase from the runway threshold until full stop. (RL 2017:03 R3)

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Preconditions

The incident occurred during a scheduled flight from Arvidsjaur to Gällivare and was conducted by the Romanian operator Carpatair. The flight was performed on behalf of the Swedish airline Nextjet within a wet lease⁹ agreement, and used the call sign Nextjet 4856.

According to interviews with the crew, the pre-flight planning was performed at Arlanda Airport before the previous sector on the same day (Arlanda – Arvidsjaur). The planning included, inter alia, the collecting of actual and forecasted weather, fuel calculations and selection of alternate airport.

At the time of the planning there was snow and rain at the destination airport with a temperature of 1°C and light north-easterly wind. The forecast indicated snowfall that was would temporarily intensify.

The snowfall meant that snow clearing was in progress at Gällivare Airport. Just over an hour before the occurrence friction coefficients of 0.55, 0.54 and 0.56 were measured with a contamination of 2 mm slush. About 20 minutes before the event new coefficients were measured with the values 0.36, 0.36 and 0.37, followed by the last measurement, 10 minutes later, with the values 0.36, 0.34 and 0.35.

1.1.2 History of the flight

The flight crew performed an approach briefing. The briefing consisted of the reading of the approach chart including temperature corrected altitudes and the configuration with 42 degrees flaps with a landing mass of 35 tons. The briefing also included the selection of approach frequencies and the transition to manual flight upon visual contact with the runway.

An instrument approach to runway 30 was initiated at approximately 21.30 hrs during darkness.

It has emerged from the voice recordings that Gällivare AFIS¹⁰ informed the flight crew about the following weather and runway conditions approximately ten minutes before landing: “wind 010 degrees, 5 knots, visibility 1 500 meters in snow and rain, vertical 800 feet, temp 0, dew point also minus 0, QNH 994” [...]”and we are still sweeping the runway, we have braking action 36, 34, 35, contamination 1 mm slush”. The information was acknowledged by the crew.

⁹ Wet lease is an agreement meaning that an operator provides aircraft, flight crew, maintenance and insurance to another airline.

¹⁰ AFIS - Aerodrome Flight Information Service.

The snow clearing of the runway progressed continuously until approximately ten minutes before landing.

About three minutes before landing the AFIS operator reported that the runway was free, the wind 030 degrees, 6 knots and that the high intensity lights were on with 100 % intensity.

The approach was conducted with full flaps and with the speed brake extended. The crew made visual contact with the high intensity approach lights at about 500 feet. The pilot in command then disconnected the autopilot. Soon thereafter, the co-pilot announced that the wind was eight knots from the right. According to DFDR-data the threshold was crossed at a normal height, 50 feet, with an indicated airspeed of 134 knots, which remained unchanged until touch down.

According to DFDR-data and interviews with the crew and ground personnel, the landing took place approximately in the touch down zone. The landing was hard. The aeroplane bounced once and thereafter veered slightly to the left.

According to the pilot in command, braking was applied immediately and the reverse levers were simultaneously brought into reverse position. The co-pilot announced *“lift dumpers out”* and *“dual reverse and speed brake”*, which meant indications in the cockpit showing that the lift dumpers on the wings upper side and the reverse buckets were deployed and that the speed brake was in an extended position.

The pilot in command has stated full braking was applied after the veer and that reverse thrust then was increased to maximum emergency reverse.

However, DFDR-data indicates that the reverse thrust increased from low idle only 20 seconds after touch down at a speed of about 50 knots. Thereafter the reverse rpm increased to about 75 % on the left engine and 65 % on the right engine.

The aeroplane overran the paved runway and stopped on the runway strip with the main wheels just over six meters after the runway end (see figure 1).



Figure 1. The aeroplane after the overrun (Photo: Lapland Airport).

The flight crew notified Gällivare AFIS about the overrun. The AFIS-operator acknowledged the message, informed the ground personnel and activated the accident alarm.

The pilot in command called “*Crew at station*” three times, which was only recorded by the Cockpit Area Microphone (CAM). Thereafter the co-pilot called “*Crew at station*” twice through the Public Address system (PA), which meant that the cabin crew should prepare itself for emergency measures.

The Senior Cabin Crew and the Swedish speaking service attendant informed the passengers in English and Swedish to remain seated and await further instructions. Meanwhile, the co-pilot informed AFIS about the need of assistance.

The flight crew started the Auxiliary Power Unit (APU), performed the engines shut down and retracted the flaps.

The ground personnel placed a stair at the aeroplanes’ main entrance door. The passengers disembarked and were transported to the airport building.

There were no injuries. Damage to the aeroplane was limited.

The incident occurred at 21.35 hrs during darkness in position 6708N 02047E, 1 027 feet above mean sea level.

1.2 Injuries to persons

	Crew members	Passengers	Total on-board	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	-	-	0	Not applicable
None	5	50	55	Not applicable
Total	5	50	55	-

1.3 Damage to aircraft

The damages, which were limited, consisted of damaged tires and engines' fan blades due to the reverse time within a restricted rpm range exceeded the maximum allowed time span.

1.4 Other damage

None.

1.4.1 Environmental impact

None.

1.5 Personnel information

1.5.1 The pilot in command

The pilot in command was 42 years old and had a valid ATPL license with flight operational and medical eligibility. At the time the commander was PF¹¹.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	5	25	216	8 285
Actual type	5	25	216	3 496

Number of landings on actual type previous 90 days: 110.

Latest PC¹² was conducted on 24 October 2015 in a Fokker 100 simulator.

1.5.2 The co-pilot

The co-pilot was 24 years old and had a valid CPL license with flight operational and medical eligibility. At the time co-pilot was PM¹³.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	5	25	228	770
Actual type	5	25	228	518

Number of landings on actual type previous 90 days: 105.

Latest PC was conducted on 3 February 2016 in a Fokker 100 simulator.

¹¹PF - Pilot Flying.

¹²PC - Proficiency Check.

¹³PM - Pilot Monitoring.

1.5.3 *Flight Duty Times*

The pilots' flight duty time was 39 hours during the last seven days. The current duty period was 7.5 hours and involved four sectors. The rest time before the duty period exceeded 10 hours. The incident occurred in connection with the fourth and final sector.

Duty times were within the prescribed time limits.

1.5.4 *Cabin crew and other personnel on board*

There were two cabin crew members. Additionally there was a service attendant from the Swedish airline Nextjet.

1.5.5 *Airport personnel*

The personnel at Gällivare airport consisted of an official responsible for flight information service (AFIS officer), and ground staff which, inter alia, managed airport maintenance such as snow removal, friction measurement and airport emergency services.

1.6 *Aircraft information*

The Fokker 100 is a twin-engine aeroplane equipped with turbofan engines. The aircraft length is just over 35 metres with a wingspan of 28 metres. The aeroplane in question was configured for 100 passengers.

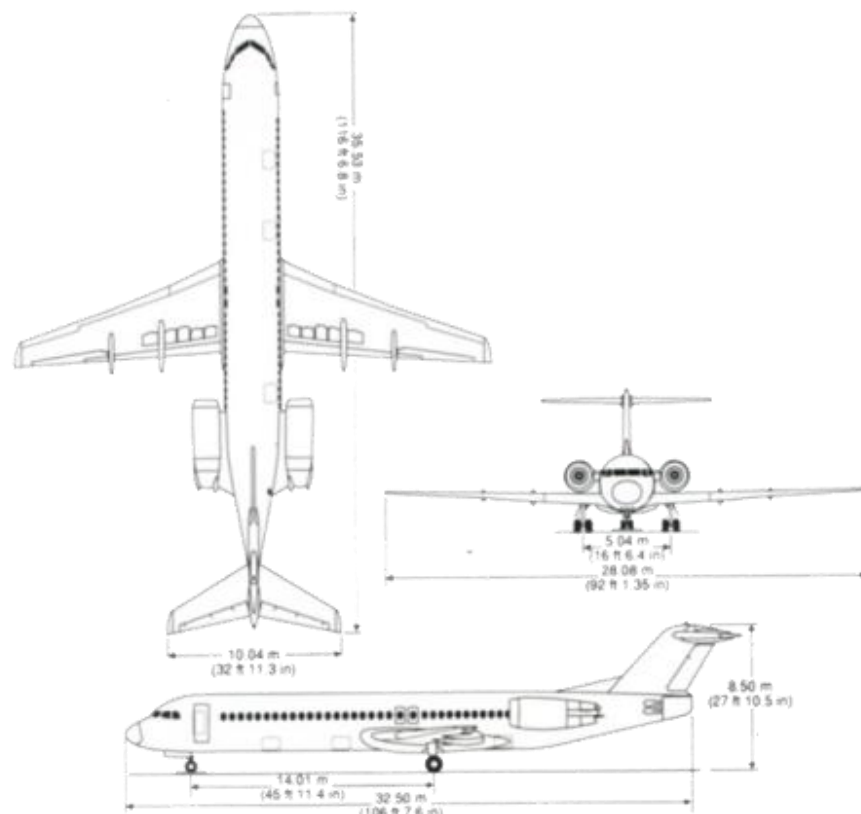


Figure 2. Three plan view of the aeroplane model from Fokker's flight manual.



Figure 3. The aircraft YR-FZA (Photo: Diogo Guimarães).

1.6.1 The aeroplane

TC-holder	Fokker Services B.V.	
Model	Fokker F28 Mark 0100	
Serial number	11395	
Year of manufacture	1992	
Gross mass, kg	Max take-off/landing mass 44 450/39 915, current 34 149kg.	
Centre of gravity	Within limits. 16 % MAC (min 7 max 35)	
Total flying time, hours	39 633	
Flying time since latest inspection, hours	7	
Number of cycles	29 174	
Type of fuel uplifted before the occurrence	JET A-1	

Engine	Rolls-Royce Tay	
TC-holder	Rolls Royce Deutschland Ltd & Co KG	
Type	Tay 650-15	
Number of engines	2	
Engine	No 1	No 2
Serial number	17653	17649
Total operating time, hours	32 181	34 186
Operating time since last overhaul, hours	6 858	1 135

Deferred remarks

No remarks relevant to the incident.

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 Description of parts or systems related to the occurrence

Flight controls

The aeroplane is equipped with a speed brake in the aft part of the fuselage. The speed brake is controlled by a lever on the centre pedestal in the cockpit. Lights on the instrument panel indicate when the speed brake is in the extended position. The speed brake can be used in flight and on the ground.

There are five panels on each wing called lift dumpers. These can only be used on the ground during landing or aborted take-off. The purpose of the device is to reduce lift, increase braking efficiency and increase drag to shorten the rollout.

The system is either automatically or manually controlled. Upon landing the automatic operation is armed with a pushbutton in the cockpit. The lift dumpers extend at main wheel rotation after touch down with the power levers in idle position.

Reverse

The engines are equipped with thrust reversers. When reverse thrust is activated, buckets are opened on the aft part of the engines which means that engine thrust is reversed and used to decelerate the aeroplane. The reverse levers are located in front of the thrust levers in cockpit.

The system is activated by lifting the reverse levers which cause the reverse buckets to open. A green light on the instrument panel illuminates when the buckets are fully open. Reverse thrust is increased by pulling the levers aft. The deceleration effect of the reverse thrust is highest at high speed.

The maximum allowed rpm during reverse is 95.5 % N1, which is indicated by a red line on the engine instruments.

There is a time limitation during reverse in the rpm range between 57 % and 75 % N1, which is indicated with amber brackets on the engine instruments (figure 4 below).

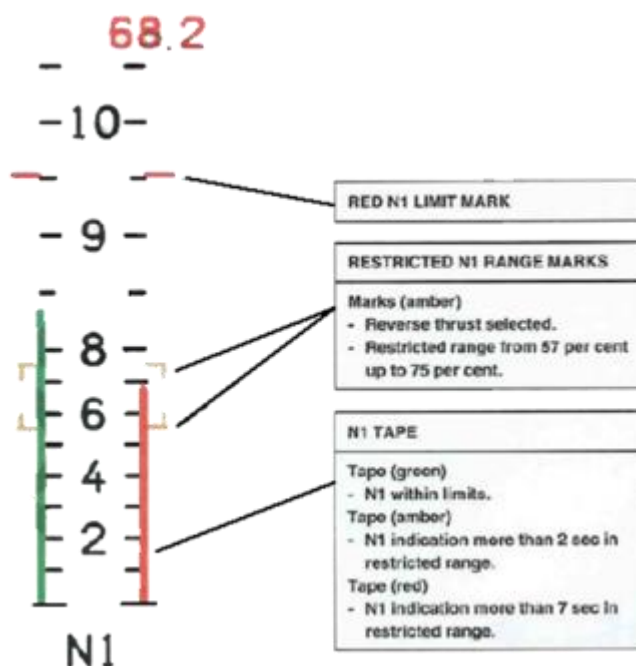


Figure 4. The amber brackets for the engine's rpm indicate the restricted N1 range. Extract from Fokker flight manual.

Brake system

The aeroplane's main landing gear has two wheels each fitted with brake discs. The brake system features an anti-skid device that prevents the wheels from locking. The aeroplane was not equipped with an automatic braking system.

Brake temperature indicators are installed on the instrument panel.

1.7 Meteorological information

According to METAR: wind 030 , 6 knots, visibility 1 500 meters in snow and rain, vertical visibility 800 feet, temperature 0°, dew point 0 C, QNH 994 hPa.

The occurrence took place during darkness.

1.8 Aids to navigation

During the event, the Instrument Landing System (ILS) for runway 30 was used.

1.9 Communications

SHK has recovered the radio communication between the flight crew and AFIS as well as Airport personnel and rescue services. Parts of radio communications that have been considered relevant to the investigation are presented in section 1 and in the analysis.

1.10 Aerodrome information

The airport is certified as an instrument aerodrome by the Swedish Transport Agency, pursuant to Chapter 6, § 6 of the Swedish Aviation Ordinance (2010:770) and in accordance with the regulation (EC) No 2016/2008 of the European Parliament and of the Council. The airport is listed in IAIP¹⁴ Sweden

The asphalt runway has the dimensions 1 714 X 45 metres. The runway has a 1 % upslope from the threshold of runway 30. The runway strip¹⁵ extends 60 metres after the threshold of runway 12.

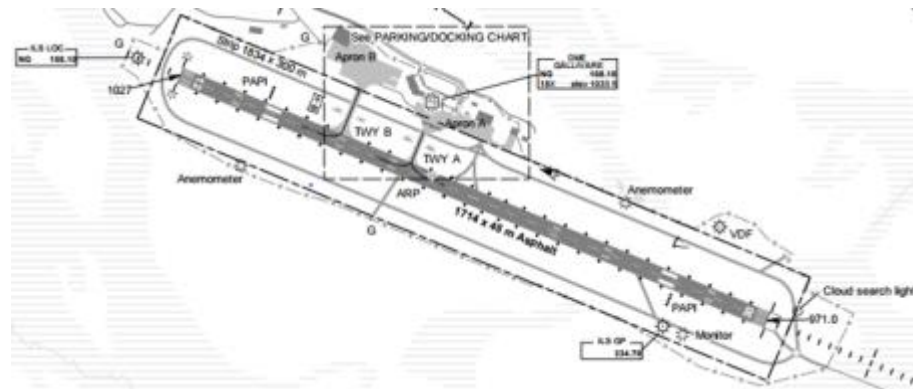


Figure 5. Aerodrome chart from IAIP.

1.10.1 Visual aids

Aerodrome lighting was in accordance to international standards and consisted of the following: high intensity approach lights, PAPI¹⁶ with a 3 degree glideslope, green threshold lights, runway edge lights and runway end lights.

The runway edge lights are placed along the entire runway length, on each side of the runway, with a spacing of 60 metres. The lights are white, except for the last 600 metres before the runway end (caution zone), where the lights are yellow.

The runway end lights consist of six red lights positioned on a line perpendicular to the runway centreline, at end of the runway.

1.11 Flight recorders

The aeroplane was equipped with a Digital Flight Data Recorder (DFDR) and a Cockpit Voice Recorder (CVR). Both units were transported by SHK personnel to the French Safety Investigation Authority (BEA) for readout. Relevant parts of the information have been used for the investigation.

¹⁴ IAIP – Integrated Aerodrome Information Publication.

¹⁵ Runway strip - means a defined area intended to reduce the risk of damage to aircraft running off a runway.

¹⁶ PAPI – Precision Approach Indicator.

1.11.1 *Digital flight data recorder (DFDR)*

The DFDR-unit was manufactured by L-3 Communications and had the part number 2100-4042-00 and the serial number 00223. A direct readout of raw data from the flight in question was performed by the French safety investigations authority (BEA), using “ROSE” software which is the manufacturer’s official equipment.

The raw data file was converted to engineering units with the assistance of the Dutch Safety Board (DSB). The conversion was made by using the aeroplane manufacturer’s parameter list and was presented in Excel files and printouts. Relevant parts of the printouts are presented in figures 6 and 7 below.

Figure 6 include the following parameters from top to bottom. The parameters marked with * are discrete parameters, meaning parameters with fixed values, i.e. on/off. The other parameters are continuous and have different values within certain limits.

- Cautions and warnings*
- Engine RPM in % (N1 and N2)
- Reverser position* (stowed or deployed)
- ILS localiser and glide slope deviation
- Flap position in degrees*
- Vertical acceleration
- Magnetic heading
- Left main landing gear on/off ground*
- Ground speed and computed airspeed
- Longitudinal acceleration
- Pitch and roll angle in degrees
- Pressure and radio altitude

The left red vertical line corresponds to the first touchdown while the other line indicates the time of the complete stop. The time span between the lines is about just over 40 seconds.

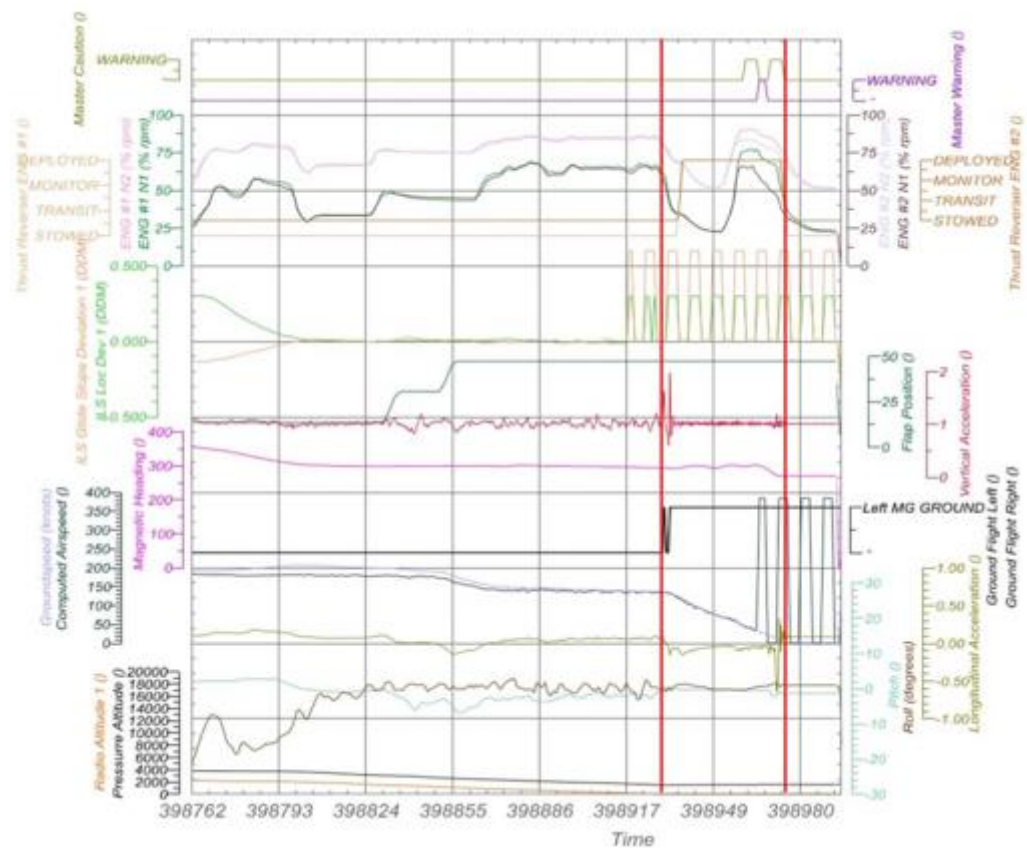


Figure 6. DFDR-data printout.

Figure 7 below is a partial enlargement of figure 6 and displays rpm in % N1 for left and right engine respectively (ENG #1, ENG #2), in green and brown colour. The red horizontal lines indicate the restricted area as described in section 1.6.2.

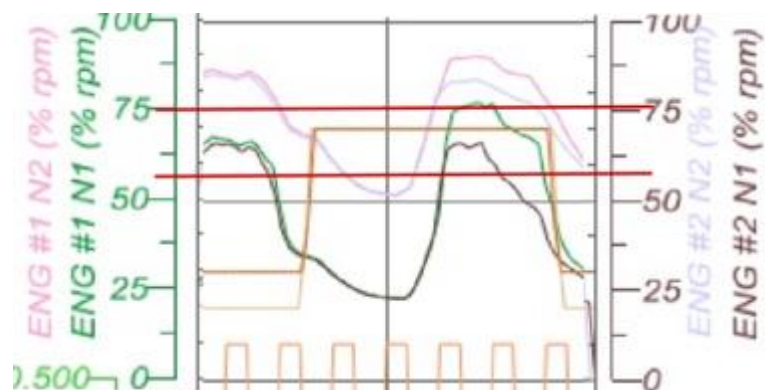


Figure 7. Detail of DFDR-data printout for engine parameters.

1.11.2 Cockpit Voice Recorder (CVR)

CVR was manufactured by L-3 communications and had the part number 2100-1020-00 and the serial number 000656481.

A direct readout was performed at the French safety investigations authority's (BEA) facilities with the software "ROSE". The downloaded raw data file was decompressed with the manufacturer's official software.

Four audio files with a length of two hours, four minutes and fourteen seconds were generated. The audio files consisted of one PA channel, two channels for left and right pilots' positions and one channel for the cockpit area sound.

Relevant parts of the sound recordings are presented in section 1.1.2.

1.11.3 Other sound recordings

SHK also recovered recordings from the AFIS-unit and from the airport's ground units including the airport's rescue services.

These recordings have been transcribed and synchronized with audio recordings from the CVR by SHK's sound expert.

1.12 Site of occurrence

The occurrence took place at the end of runway 30 at Gällivare airport. The aeroplane came to a complete stop on the runway strip. The area was covered by snow.

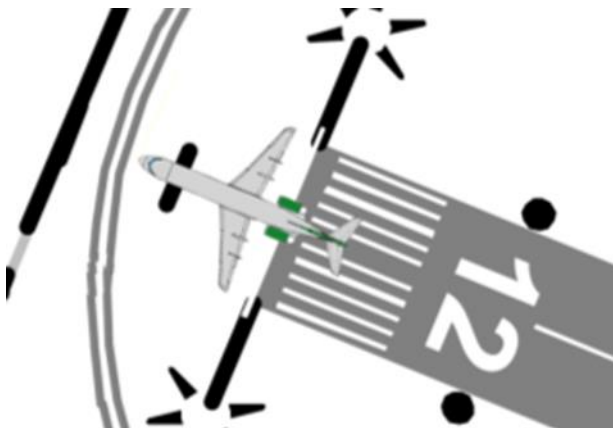


Figure 8. The aeroplane's position after the excursion.

1.13 Medical and pathological information

Nothing has emerged indicating that the pilot's mental or physical condition was impaired before or during the flight.

1.14 Fire

There was no fire.

1.15 Survival aspects

Not applicable.

1.15.1 Rescue operation

The airport accident alarm was activated during the event. One of the airport rescue service's vehicles drove out to the aircraft. The rescue operation was cancelled because there were no injuries or signs of fire. The ELT¹⁷ of the type ELTA A06 was not activated.

1.16 Tests and research

1.16.1 Landing performance

The Fokker 100 is an aircraft in performance class A.

For calculation of landing performance two terms are used:

- Dispatch (planning before the flight)
- Inflight (during the flight)

According to Commission Regulation (EU) No 965/2012 the pre-flight planning and determination inflight shall be carried out as follows:

Dispatch

The aeroplane's actual landing distance (ALD) is the distance from 50 feet over the runway threshold to a full stop, see figure 9 below.

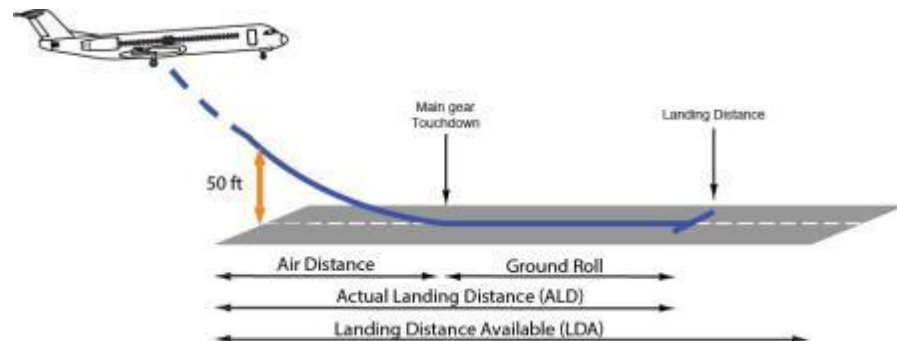


Figure 9. Actual and available landing distance.

Immediately after landing maximum wheel braking is assumed. ALD is produced by the manufacturer during the test flight during certification of the aeroplane.

ALD should be corrected for:

- Temperature
- The runway slope
- Barometric pressure (QNH)
- Landing mass
- Wind
- Airport elevation

¹⁷ ELT (Emergency Locator Transmitter).

Planning of the required landing distance (RLD-Dispatch) shall be performed as follows:

For a dry runway the ALD represents 60 % of RLD (thrust reversers not to be included in the calculation).

For wet runway (RLD_{WET}) the basis for a dry runway (RLD_{DRY}) is used with a further addition of 15 % (thrust reversers not to be included in the calculation).

The determination of landing performance for a contaminated runway (RLD_{CONTA}) requires specific calculations.

The actual landing distance shall be equivalent to the calculation for RLD_{CONTA} with a supplement of 15 %. The calculated value shall be less than RLD_{WET}. For landing on contaminated runways, manufacturers provide performance data with detailed instructions on the use of anti-skid, reversers, speed brakes and/or spoilers.

Inflight

Determination of required landing distance inflight is performed as follows:

Before commencing an approach to land, the pilot in command shall be satisfied that, according to the information available to him/her, the weather at the aerodrome and the condition of the runway intended to be used should not prevent a safe approach, landing or missed approach, having regard to the performance information contained in the operations manual.

The in-flight determination of the landing distance should be based on the latest available meteorological or runway state report, preferably not more than 30 minutes before the expected landing time.

Definition of contamination with slush

According to EASA, contaminated runway means a runway of which more than 25 % of the runway surface area within the required length and width being used is covered by surface water more than 3 mm (0,125 in) deep, or by slush, or loose snow, equivalent to more than 3 mm (0,125 in) of water.

Landing performance during the incident flight

With the reported friction coefficients of 0.36, 0.34, and 0.35, the performance calculation displays a value below maximum landing mass and could be used to fulfil the requirement with adequate margins. With the actual landing mass of 34 149 kg the friction coefficients could be as low as 0.20 (see figure 10 below).

		Landing field length - Slippery Runway / Norm. Max. rev. thrust / 15 % margin										MLM 39915
FLAPS A/S	WIND	REPORTED BRAKING ACTION										
		Good 0.40	Medium to Good 0.38	0.36	0.34	0.32	Medium 0.30	0.28	Medium to Poor 0.26	0.24	0.22	Poor 0.20
42°	T 10	33194	33194	33194	33194	33194	33194	33194	32765	30273	NA	29174
	T 5	38608	38608	38608	38608	38608	38608	38608	37933	35137	32484	30774
	Opel 0 (Calm)	39915	39915	39915	39915	39915	39915	39915	39915	39915	38101	35153
	H 5	39915	39915	39915	39915	39915	39915	39915	39915	39915	39915	37248
	H 10	39915	39915	39915	39915	39915	39915	39915	39915	39915	39915	30689

Figure 10. The operator's performance data for slippery runway indicating that maximum landing weight (39 915 kg) could be used to stop the aircraft with 15 % margin (red mark) with braking action 0.34.

Before landing the reference speed for the approach (V_{REF}) is determined by means of a speed booklet. At a landing mass of 35 tons V_{REF} is 122 knots with 42 degrees of flap (see Figure 11 below).

VM		FL 350	Carpatair	
186	▶▶▶	FL 280	F 100 / 10.04.2006	
177		FL 220	LANDING	
169		FL 150		
VFTO		GROUND		
165				
TAKE-OFF-G/A				
β^*	VR	VGA V2		
0	128	VFR134		
8	122	127		
15	118	123		

β^*	VR	VM
0	145	165
8	138	155
25	131	141
		WEIGHT (T)
42	122	35

ADD 1 KT TO V1 AND VR FOR EACH 5°C ABOVE 30°C OAT

Figure 11. Speed booklet for landing mass 35 tons.

1.16.2 Correlation between reported braking coefficient (μ) and braking performance

Airports release a friction coefficient derived from a measuring vehicle. This friction coefficient is termed as "reported μ ". The actual friction coefficient, termed as "effective μ " is the result of the interaction tire/runway and depends on the tire pressure, tire wear, aircraft speed, aircraft weight and anti-skid system efficiency. There is no way to establish a clear correlation between the "reported μ " and the "effective μ ". "Reported μ " also varies between different measuring equipment. This means that it is not appropriate to use only "reported μ " to calculate landing performance.

The presence of fluid contaminants (water, slush and loose snow) on the runway surface reduces the friction coefficient even more and may lead to aquaplaning (also called hydroplaning).

According to EASA Guidance Material to Annex IV – part ADR-OPS Subpart A pertaining to the regulation (EU) 139/2014, friction coefficients may be unreliable when the runway is contaminated with slush, wet snow and wet ice.

The Norwegian Safety Investigation Authority (SHT) has published a thematic investigation (SL 2011/10) dealing with flight under winter conditions, friction measurement and conditions for predictions of friction values. The report states that braking coefficients measured in conditions with small differences between temperature and dew point

is not reliable. The report also states that the effect of the reverse thrust represents about 20 % of the total braking power.

1.16.3 Airport winter maintenance

Regulations

According to the EASA Guidance Material regarding operational requirements for airports (ED Decision 2014/012/R) pertaining to the regulation (EU) 139/2014 and the Swedish Transport Agency's regulations (TSFS 2010:119) and general advice on the operation of an approved airport, the runway shall be kept as clean as possible. Friction coefficients shall be measured and reported.

There should be a system for airport maintenance. The system should at least enable the following:

- 1) precipitation and other deposits on the runway system, apron and adjacent surfaces to be removed, and that the remaining ice and snow on the adjacent surfaces are profiled to avoid any hazard to the aircraft,
- 2) the friction coefficient on the runway and, if possible, other paved surfaces used for flight operations, is measured and monitored,
- 3) additional measures are taken in order to maintain the friction required for paved surfaces, where the objective of the measures shall be to achieve friction coefficients exceeding 0.40, and
- 4) the friction coefficients of the paved surfaces are measured and monitored for maintenance purposes.

On runways used by aircraft with a maximum take-off mass of 10 000 kg or more or with an approved passenger seating configuration of 20 passengers or more, the friction should be measured with an equipment that records the values continuously on a printer strip, which indicates the friction coefficient with a braked wheel.

The airport's manual is based on Swedish regulations. The manual also contains information about above mentioned requirements and guidance material,

Friction measurement equipment

Friction measurement is performed at the airport with a device of the type Skiddometer BV-11 (figure 12). The equipment was completely overhauled in 2014. Yearly maintenance and calibration was satisfactorily performed on 24 November 2014.



Figure 12. Vehicle with Skiddometer BV-11 (Photo: Lapland Airport).

Snow removal was performed with vehicles of the type Volvo FM9 and sweepers/blowers of the type Överåsen RS200 and Vammas SB3600H (figure 13).



Figure 13. Snow removal equipment (Photo: Lapland Airport).

Friction measurement

The friction coefficient on a runway shall be reported for each third of the runway from the threshold with the lowest runway designation. The estimated friction coefficient corresponds to estimated braking action and the code numbers 5-1 and 9 according to figure 14 below:

Code	Measured friction coefficient	Estimated braking action
5	0.40 and more	GOOD
4	0.39 – 0.36	MEDIUM to GOOD
3	0.35 – 0.30	MEDIUM
2	0.29 – 0.26	MEDIUM to POOR
1	0.25 and below	POOR
9	unreliable	UNRELIABLE

Figure 14. Table from ICAO Airport Service Manual, Doc 9137 and TSFS 2010:137, regulation on airport data.

If the airport is using approved equipment for friction measurement, and conditions are acceptable for this equipment, the measured

friction coefficient and the type of equipment used shall be reported.

The airport's manual states that if there is reason to suspect that the obtained measurement is misleading, e.g. due to malfunction of the measuring equipment, "runway braking action is not possible to measure" and "code 9" shall be reported. When a thin layer of dry snow or slush covers the runway, and the speed of the measuring equipment is below 95 km/h, "code 9" shall be reported.

Friction measurement during the event

In order to start the measurement the equipment's measuring wheel must be lowered to the surface, which only can be done after the equipment is aligned with the runway. This means that only 1 600 meters of the total runway length of 1 714 meters is reported in the measurement protocol. The runway length is divided into three equal sections, designated "A, B and C".

The measurement starts at the threshold of runway 12 and is conducted five meters to the side of the centre line of sections A, B and C. Then, a measurement is made in the opposite direction of the sections C, B and A, five meters from the centre line the other side.

The measurement protocol below (figure 15) shows the last measurement prior to the event. The bold line shows the friction values for both runway directions.

The thin line shows the vehicle speed in km/h. The best possible reliability is achieved at a speed of 95 km/h. As the vehicle needs acceleration and braking distance at each runway threshold, the entire runway cannot be measured with a speed of 95 km/h, which results in a deterioration of the measurement accuracy. As the touchdown zone starts about 300 meters after the threshold, less than half of the first third of the measurement is usable.

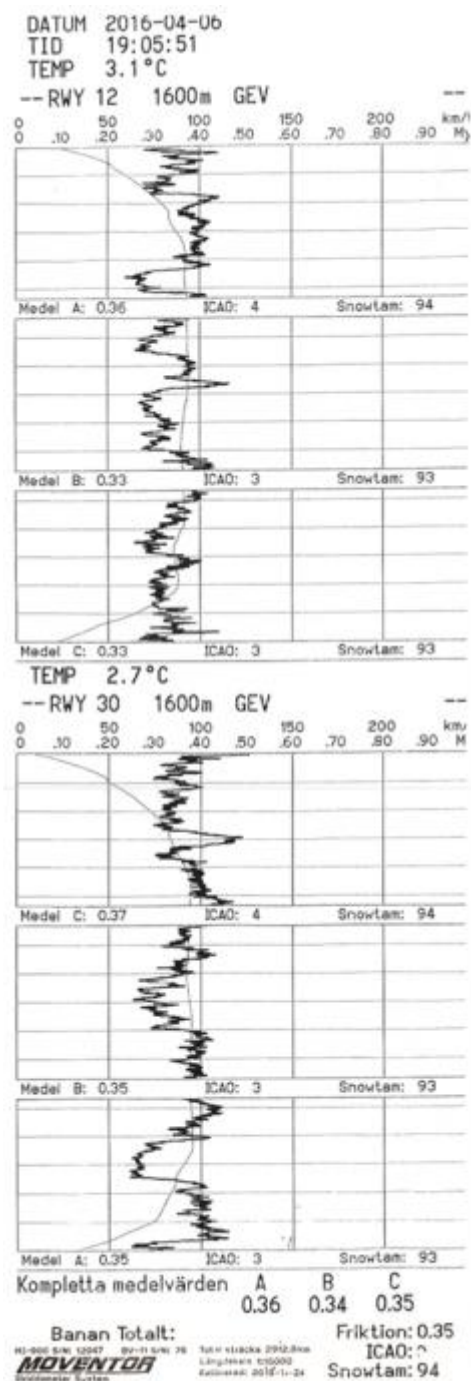


Figure 15. Measurement protocol with friction coefficients from Lapland Airport.

1.17 Organisational and management information

1.17.1 The operator

Carpatair S.A. is an air carrier engaged in commercial air transport with passengers. The company had a valid Romanian AOC with the number RO-003, issued by the Romanian Aviation Authority. The operator had, inter alia, three aeroplanes of the type Fokker 100.

1.18 Additional information

1.18.1 Stabilised approach

Stabilised approach (SAp) is defined, according to the regulation (EU) 965/2012 as an approach that is flown in a controlled and appropriate manner in terms of configuration, energy and control of the flight path from a pre-determined point or altitude/height down to a point 50 feet above the threshold or the point where the flare manoeuvre is initiated if higher.

Stabilised approach is described I Part B of the operator's operations manual.

General recommendations about stabilised approach indicate that the speed should be in a range between V_{REF} and $V_{REF} + 20$ knots. If the speed falls below V_{REF} or $V_{REF} + 20$ is exceeded, the approach should be interrupted and a go-around initiated.

1.18.2 Approach procedures

The operator's Operations Manual Part B (OM-B) mentions callouts (meaning operational communication consisting of challenges and responses). According to OM-B 2.4.13.2, the selected speed shall be called out at flaps extension to 25 and 42 degrees.

1.18.3 Speed and reverse thrust on short runways

According to the aeroplane manufacturer's flight manual, the speed over the threshold shall be V_{REF} when landing on short runway and the thrust shall be reduced to idle.

The following procedures are described in the operator's operations manual, part B (OM-B) section 2.4.15.2, Use of Reverse on short field landing:

Immediately after main landing gear touchdown PF (Pilot Flying) selects idle reverse. Do not delay nose gear touchdown.

At nose gear touchdown increase both reversers as follows:

- Emergency reverse on the Fokker 100 (levers fully back to the stop). Reverse is most effective at high speed and least effective at the end of the landing roll.
- Delaying reverse for more than 5 seconds after touchdown means the engines have gone from approach idle to low idle with loss of reverse response.
- PM (Pilot Monitoring) monitors N1 to avoid the restricted range between 57-75 % N1 and calls: "*N1 checked*" or "*increase N1/reduce N2*" (as required). Stabilised operation in the restricted range is prohibited and transit through this range

must be as short as possible (less than 7 seconds) to avoid maintenance requirements.

- Whenever N1 is within the reverse thrust 57-75 % for more than 2 seconds the affected N1 tape colours amber, a level 2 alert. “N1 REV RESTR ENG 1(2)” is presented. This message is an advisory and no maintenance action and /or technical log entry are required.
- Whenever N1 remains within the reverse thrust 57 -75 % for 7 seconds or more, the affected N1 tape colours red, a level 3 alert “N1 REV RESTR ENG 1(2)” is presented and a status message “FAN1(2) INSP REQD” is displayed (which implies maintenance action before the next flight).

1.18.4 Actions taken

On 11 April 2016, after the occurrence, the operator reviewed the existing Risk Assessment for winter flights into the airports Gällivare and Arvidsjaur, originally issued on 21 December 2015. The operator also issued a memorandum to reduce weather-related risks during flight operations.

The risk assessment underlines, inter alia, the importance of using maximum reverse immediately after touchdown.

The memorandum also emphasizes the importance of careful planning regarding weather conditions. It also points out the risks associated with flight on the same sectors during a long period of time and mentions that a routine state of mind may develop, which can reduce the level of situational awareness and overall attention below optimal levels.

1.18.5 Runway excursions

IATA¹⁸'s safety report 2015 has identified three primary risk areas: Loss of Control In-flight (LOC-I), Controlled Flight into Terrain (CFIT) and Runway Excursion (RE). The first two categories represent the primary cause of fatal accidents, while Runway Excursions accounted for the majority of the accidents in the past five years. The report further states that 86 % of the Runway Excursion during the five years between 2011 and 2015 occurred during the landing phase.

¹⁸ IATA – International Air Transport Association.

1.18.6 Safety during the landing phase

IATA has also published the document “Unstable Approaches: Risk Mitigation Policies, Procedures and Best Practices”. According to the document, approach and landing phases of flight account for the major proportion of all commercial aircraft accidents; 64 % of the total accidents recorded from 2010-2014. Unstable approaches were identified as a factor in 14 % of those accidents.

The document further presents reasons to initiate a go-around when the safety of a landing is compromised, inter alia:

- Landing runway occupied.
- Aircraft malfunctions or erroneous indications.
- Sudden/un-forecasted tailwind, windshear or precipitation.
- Long flare or floated landing.

EASA published a Safety Information Bulletin (SIB No: 2013-20) about bounced landing recognition and recovery training. The bulletin lists the casual factor that can lead to bounced landings; excess airspeed and/or incorrect flare technique and power management are the main factors.

EASA also published European Plan for Aviation Safety (EPAS) 2016–2020, dated 25 January 2016. One of the scopes and objectives is to reduce the number of runway excursions in fixed-wing commercial operation.

The safety actions related to runway safety cover, inter alia, the introduction of on board technology to provide information to the pilot on remaining runway left available, aeroplane performance and prediction of wind shear.

EPAS is also fostering the implementation of the European Plan for the Prevention of Runway Excursions (EAPPRE) which addresses several recommendations to the operators related to the landing phase.

1.19 Special methods of investigations

Not applicable.

2. ANALYSIS

2.1.1 *Preconditions*

The flight and landing preparations

During the pre-flight planning carried out at Arlanda airport, winter conditions were reported at Gällivare airport with good braking actions.

The pilots had operational experience since the beginning of the winter of the current sectors and were familiar with the airport and the aeroplane type.

Since the runway at Gällivare airport was shorter than 1 800 meters, specific operational procedures applied regarding aeroplane configuration, speed and the use of brakes and engine reverse.

According to voice recordings, the pilots conducted a briefing for the approach but did not mention performance calculations, including runway conditions, approach speeds, the use of reverse and braking, which should have been done according to the operator's operations manual (OM-B). The pilots' previous landing experience at the airport in winter conditions may explain that specific landing calculations were not mentioned.

The lack of a review of these items probably meant that the preconditions for a safe landing deteriorated.

Winter maintenance at Gällivare Airport

The weather at the airport deteriorated, which called for snow removal and friction measurement. The equipment used consisted of snow clearing and friction measurement vehicles that fulfilled prescribed maintenance and calibration criteria.

Snow removal and friction measurements were performed continuously. The two last friction measurements resulted in similar values and were carried out under similar weather conditions. This may explain that an additional friction measurement was not performed immediately before landing as the ground personnel did not have any reason to expect large changes concerning friction coefficients.

The friction measurements were performed at the required speed of 95 km/h on the part of the runway where it was possible to achieve this speed, and no malfunction of the equipment was noted. In view of what is stated in the aerodrome manual, it is understandable that the friction coefficient was not considered as unreliable.

Reporting of runway conditions

The runway condition reports performed by the AFIS operator contained information about friction coefficients and slush contamination. However, as the contamination was less than 3 mm, the runway was not considered contaminated according to EASA's definition.

2.1.2 The course of the event

About ten minutes before the approach the pilots were informed that the friction coefficient was 0.36, 0.34 and 0.35, the temperature 0 and the dew point minus 0 and that the runway was contaminated with 1 mm of slush. This means, as presented in section 1.16.2, that the reported friction coefficients probably were unreliable.

The absence of specific information in the operator's manuals on the unreliability of friction coefficients under such circumstances can explain that the pilots did not take any special action for this reason.

The aircraft was configured in accordance with the operator's procedures for short runways which meant the use of full flaps (42 degrees) and speed brake. Callouts regarding the speeds associated with the extension of the flaps to 25 and 42 degrees were not recorded by the Cockpit Voice Recorder (CVR).

The pilot in command stated that the speed was $V_{REF} + 5$, corresponding to 127 knots, over the runway threshold. However, according to DFDR-data, the indicated airspeed over the threshold was 134 knots (12 knots over V_{REF}) and was unchanged until touch-down. The excess speed is within the limits of the general criteria for stabilised approach, but does not meet the aircraft manufacturers or the operator's criteria indicating that the runway threshold speed shall be V_{REF} . The lack of communication between the pilots associated with the extension of full flaps may explain why the speed was not set to the correct values.

The absence of speed reduction at touch-down is probably due to a late thrust reduction to idle. According to the aircraft manufacturer, the thrust reduction shall be performed over the runway threshold.

DFDR data indicate a hard landing with a bounce, and displacement in yaw which was probably caused by an insufficient flare and high speed, combined with crosswind. The pilot in command has stated that braking was initiated immediately and that the reverse thrust was activated. However, the pilot in command delayed the increase of reverse thrust due to the yaw.

The pilot in command has stated that reverse thrust soon thereafter was increased maximum emergency reverse. Maximum rpm for emergency reverse is 95.5 % N1. DFDR-data indicate, however, that the reverse rpm only increased to about 75 % N1 and 65 % N1 for the

left and right engine, which took place about 20 seconds after touchdown and at a speed of about 50 knots. Since the engine speed was in the restricted area cautions were activated. CVR recordings did not reveal any callouts concerning the engines rpm in this area.

The low reverse rpm together with the low speed meant that the effect of the reverse was almost absent.

DFDR-data indicate that the longitudinal acceleration during the rollout averaged -0.07 G until the reverse rpm started to increase. This indicates that the wheel brakes had no effect during period, which either might be caused by the absence of brake application, or by a very low friction coefficient. The pilot's statement that the brake temperature indicated low values after landing is also indicates that the wheel brakes had no effect.

SHK is therefore unable to determine whether the slow deceleration was due to the absence of brake application, or to the friction coefficient being lower than measured.

The absence of maximum emergency reverse immediately after touchdown can be explained by the yaw displacement that occurred. The delay of about 20 seconds is probably due to the lack of engine instruments monitoring. As mentioned above, the approach briefing did not mention any information about the use of reverse and brakes, which may have contributed to reduced attention in these areas.

There are no standard procedures regarding cockpit cooperation, such as callouts, when it comes to monitoring of deceleration and reverse rpm after landing. In SHK's opinion, this is a shortcoming that can contribute to this type of events.

The crew informed the AFIS operator about the excursion and decided that that an emergency evacuation was not necessary, which is understandable as the aeroplane had stopped on the runway strip without any visible damage.

2.1.3 Overview of the occurrence

Flight operations in winter conditions on short and contaminated runways, together with temperatures around zero places high demands regarding planning and flying.

This is partly because friction coefficients measured under such conditions are not reliable, and partly due to the lack of a clear correlation between the reported friction coefficients and the aircraft's effective friction coefficient.

2.1.4 Risk mitigation

In order to reduce the risk of similar incidents in the future, it is necessary to increase the knowledge and awareness of the factors that reduce safety margins during flight operations on runways in winter conditions. This can only be achieved by ensuring that regulators and commercial operators establish improved procedures for planning and execution, and by improving initial and recurrent training of flight crews.

As mentioned in section 1.18.1 above, general recommendations are established for stabilised approach until crossing of the runway threshold. There are currently no recommendations for the final part of the approach, from the threshold to positive touchdown and full stop.

With correct technique, it is fully possible to implement a safe go-around in this phase. There are situations, as in the case of high landing speed, where a go-around may be preferable compared to a landing. Examples of others situations are landing past the touchdown zone or unsafe deterioration of yaw control prior to touchdown.

The European Plan for Aviation Safety (EPAS) and the European Plan for the Prevention of Runway Excursions (EAPPRE) include future actions which are promoting an increased level of landing safety.

In SHK's opinion, some of these actions could be implemented at an earlier stage.

SHK considers, for these reasons, that the airline industry and regulators should examine the possibility of introducing a Safe Landing concept (see figure 16).

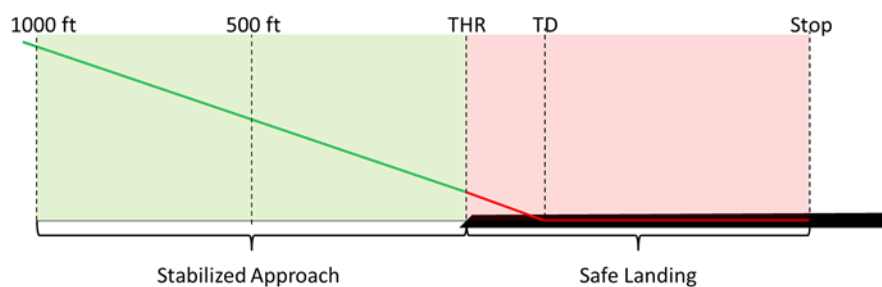


Figure 16- Safe Landing concept.

Figure 16 shows in a comprehensive manner the parts of the landing stage where there presently is an established operational concept (stabilized approach - green) and the parts where there is no such concept (at the crossing of the runway threshold - red).

A Safe Landing concept could include, but not be limited to the following:

- Crossing the threshold at appropriate speed.
- Monitor appropriate speed reduction from the threshold until touchdown.
- Touchdown on the appropriate, and agreed upon, point on the runway.
- Initiate a go-around if appropriate speed, speed reduction, or touch down point is not achieved.
- Appropriate use of retardation devices such as speed brake, lift dumpers, reverse and brakes.

The European Plan for Aviation Safety (EPAS) and the European Plan for the Prevention of Runway Excursions (EAPPRE) contain future actions that promote an increased level of safety during landing.

As far as SHK has noted, the planned measures do not take into account all parts of what SHK has described above as a concept for safe landing.

3. CONCLUSIONS

3.1 Findings

- a) The crew was qualified to perform the flight.
- b) The aeroplane had a Certificate of Airworthiness and valid ARC.
- c) The approach briefing did not include runway conditions, final approach speeds, use of reverse and brakes.
- d) Prevailing meteorological conditions probably meant that the reported braking coefficients were unreliable.
- e) The airspeed was not reduced from threshold to touchdown.
- f) Reverse rpm was increased only 20 seconds after touchdown.
- g) The aeroplane overran the runway and stopped on the strip.
- h) ELT was not activated.
- i) The AFIS operator activated the accident alarm.
- j) A normal disembarkation was performed.
- k) The rescue effort was cancelled.
- l) There were no injuries.
- m) The aeroplane was slightly damaged.

3.2 Causes and contributing factors

The serious incident was caused by the gradual decrease of the conditions for a safe landing, which was not perceived in due time.

Contributing factors:

- The airspeed did not decrease from 50 feet's height to touchdown.
- The reported friction coefficients were probably unreliable.
- The wheel brakes were probably not fully applied due to the initial yaw disturbance.
- The reverse rpm increased only 20 seconds after touchdown.

4. SAFETY RECOMMENDATIONS

ICAO is recommended to:

- Work for the introduction of a generic Safe Landing concept including the flight phase from the runway threshold until full stop. (RL 2017:03 R1)

EASA is recommended to:

- Work for the introduction of a generic Safe Landing concept including the flight phase from the runway threshold until full stop. (RL 2017:03 R2)

The Swedish Transport Agency is recommended to:

- Work for the introduction of a generic Safe Landing concept including the flight phase from the runway threshold until full stop. (RL 2017:03 R3)

The Swedish Accident Investigation Authority respectfully requests to receive, **by 9 June 2017 at the latest**, information regarding measures taken in response to the safety recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas

Nicolas Seger