Statens haverikommission
Swedish Accident Investigation Authority

Final Report RL 2017:06e

Accident at Nynäs Fallet, Örebro County, on 10 May 2016 involving the hot air balloon SE-ZOU of the model LBL 120A, operated by Ballongflyg i Väst AB.

Reference no. L-46/16

2 June 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.

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This document is a translation of the original Swedish report. In case of discrepancies between this translation and the Swedish original text, the Swedish text shall prevail in the interpretation of the report.

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Content

General observations 5
The investigation 5
SUMMARY 8
1. FACTUAL INFORMATION 10
1.1 History of the flight 10
1.1.1 Circumstances 10
1.1.2 Sequence of events 11
1.2 Injuries to persons 14
1.3 Damage to aircraft 14
1.4 Other damage 14
1.4.1 Environmental impact 14
1.4.2 Other damage 14
1.5 Personnel information 14
1.5.1 Pilot in command 14
1.5.2 The pilot's duty schedule 14
1.5.3 Other personnel affected 14
1.6 Aircraft information 15
1.6.1 Hot air balloon 15
1.6.2 The top vent 15
1.6.3 The balloon’s operation 15
1.7 Meteorological information 16
1.7.1 Meteorological conditions 16
1.7.2 Meteorological forecasts 16
1.7.3 Meteorological conditions at the time of the accident 19
1.7.4 Wind gradient 20
1.8 Aids to navigation 21
1.9 Communications 21
1.10 Aerodrome information 21
1.11 Flight recorders 21
1.12 Accident site and aircraft wreckage 22
1.12.1 Accident site 22
1.12.2 Aircraft wreckage 23
1.13 Medical and pathological information 23
1.14 Fire 23
1.15 Survival aspects 23
1.15.1 Rescue operation 23
1.15.2 Position of and injury to those on board and use of safety belts 23
1.16 Tests and research 24
1.17 Organisational and management information 24
1.17.1 The operator 24
1.17.2 The operator’s descriptions for weather information 24
1.17.3 Operational limitations for flight 25
1.18 Additional information 25
1.18.1 Regulations with requirements on the pilot’s experience 25
1.18.2 Regulations on weather conditions 25
1.19 Special methods of investigation 26
2. ANALYSIS 26
2.1 Flight planning 26

2.1.1 Margins to forecasted significant aviation weather 26
2.1.2 Sources of information on aviation weather 27
2.1.3 External pressure to perform the flight 27
2.2 The landing 28
2.3 Use of safety harness 28
2.4 The pilot's qualification and training 29
3. CONCLUSIONS 30
3.1 Findings 30
3.2 Causes 30
4. SAFETY RECOMMENDATIONS 31

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 10 May 2016 that an accident involving a hot air balloon with the registration SE-ZOU had occurred at Nynäs Fallet, Örebro County, on the same day at 21:08 hrs.

The accident has been investigated by SHK represented by Mrs Helene Arango Magnusson, Chairperson, Mr Ola Olsson, Investigator in Charge, Mr Sakari Havbrandt, Operations Investigator and, until 23 September 2016, Mr Jens Hjortensjö, Investigator Behavioural Science.

The investigation team of SHK has been assisted by Mr Stefan Hansson as an expert in hot air balloon operations.

Mr Marcus Cook from the Air Accidents Investigation Branch (AAIB) has participated in the investigation by representing the type certificate holder of the hot air balloon and the burner.

The investigation was followed by Mr Magnus Axelsson of the Swedish Transport Agency.

The investigation was followed by Ms Raluca-Maria Negoescu of the European Aviation Safety Agency (EASA).

The following organisations have been notified: The European Aviation Safety Agency (EASA), the European Commission, the United Kingdom Air Accidents Investigation Branch (AAIB) and the Swedish Transport Agency.

Investigation material
Interviews have been conducted with the pilot and the two passengers and with several witnesses on the ground.

A meeting with the interested parties was held on 14 November 2016. At the meeting SHK presented the facts discovered during the investigation, available at the time.

Final Report RL 2017:06e

Aircraft:	
Registration, type	SE-ZOU, Lindstrand A Type Hot Air Balloons
Model	LBL-120A
Class, Airworthiness	Normal, Certificate of Airworthiness and valid Airworthiness Review Certificate (ARC)[1]
Serial number	1423
Holder	Ballongflyg i Väst AB
Time of occurrence	10 May 2016, at 21:08 in daylight hrs. Note: all times are given in Swedish day-light saving time (UTC[2] + 2 hrs)
Place	Nynäs Fallet, Kumla, Örebro County, (position 59º10N 015º19E, 45 metres above mean sea level)
Type of flight	Commercial air transport with hot air balloon
Weather	According to SMHI's analysis: Wind: West 5 knots, at around 21:00 hrs rapid change to north-northeast 15-20 knots, gusty winds. Visibility: More than 10 km. Cloud: None below 5 000 feet. Temp: +20-24ºC, behind the cold front approximately +15ºC. Dewpoint: +1ºC, behind the cold front approximately +6ºC. QNH[3] 1015 hPa, rising.
Persons on board:	3
Crew members	1
Passengers	2
Injuries to persons	Serious
Damage to aircraft	Substantially damaged
Other damage	Damage to a power line
Pilot:	
Age, licence	31 years, FB[4]
Total flying hours	389 hours, of which 84 hours on type
Flying hours previous 90 days	2 hours, both on type
Number of landings previous 90 days	2

[1] ARC – Airworthiness Review Certificate.
[2] UTC – Coordinated Universal Time.
[3] QNH – Indicates barometric pressure adjusted to mean sea level.
[4] FB - Balloon Pilot License.

SUMMARY

The intention of the flight was a hot air balloon flight experience with two passengers. The weather forecasts showed that the wind strength would increase during the evening because a sharp cold front was moving south over Svealand[5] during the afternoon and evening.

The hot air balloon lifted off just after eight o'clock in the evening in favourable weather conditions. The flight time was calculated to be one hour. After about 40 minutes flight, a significant weather change in the form of fog was observed. The pilot decided to immediately abort the flight and commence descent. Before the landing could be commenced, the wind changed direction and strength, which made a landing at the first designated site impossible, upon which the pilot selected a new landing site.

The first touchdown was very hard. Both the rate of descent and the speed were high. All those on board lost their balance and fell over. In connection with this, the pilot happened to inadvertently put the burners on full power. This contributed to the balloon climbing to an altitude of 30-50 metres. Shortly thereafter, the pilot succeeded in shutting down the burners.

A second hard touchdown was made after about 1 000 metres. The balloon basket was then pulled along the ground and was at times in the air a little above the ground. The system for a rapid deflation of the balloon’s hot air was not activated in connection with this touchdown.

About 400 metres after the second touchdown, the pilot fell out of the balloon basket. The balloon then climbed with only the two passengers on board. The passengers, however, operated the top vent so that the balloon again descended towards the ground. They subsequently decided to leave the balloon. In conjunction with this, the first passenger became caught for a short while between the basket and the ground. The second passenger's foot became tangled in an operating line. Held fast by the line, the passenger was dragged behind the balloon for several hundred metres before the balloon drifted into a power line and stopped.

The pilot and one of the passengers were seriously injured, while the other passenger received minor injuries.

In light of the weather information that was available, it is SHK’s view that the margin appears too small between the time of planned completion of the flight and the time at which there was reason to assume that the weather could deteriorate drastically. However, there are no rules regarding time margins between planned flight and forecasted significant aviation weather. In SHK’s view, the introduction of such rules could reduce the risk of accidents of this type.

When the hard landing occurred, the pilot was not wearing the safety harness that was in the basket. However, there are no explicit rules regarding the conditions in which the pilot is to put on the safety harness. National rules will soon

[5] Region located in south central Sweden.

be replaced by common European rules. According to the proposals for new rules, the actual type of balloon will no longer be subject to any safety harness requirements. As the event shows that there is a risk that the pilot will fall out of the basket even in the actual type of balloon, SHK believes that EASA should consider introducing safety harness requirements for all types of balloons in commercial air transport and to clarify when it will be used.

The accident was caused by the following factors:

- The flight was planned with a too small, albeit permitted, time margin to forecasted significant weather conditions that could impair a safe flight.

- A high speed and rate of descent during the landing caused the touchdowns to be very hard. In addition, after a hard ground contact, the pilot fell out of the basket and thereby lost the ability to control the balloon.

- The system for a rapid deflation of the balloon's hot air was not activeted in connection with the second touchdown.

Safety recommendations

The Swedish Civil Aviation Authority's regulations (LFS 2007:48) on commercial air transport with manned hot air balloon are currently applicable. New regulations for balloon flight, which will replace the national rules, are being drafted at EASA and are planned to be introduced in 2018. With reference to this, SHK does not deem it appropriate to recommend amendments to the current regulations but instead chooses to direct its recommendations to EASA.

EASA is recommended to:

- Consider introducing time margins between planned landing time and significant weather conditions. (*RL 2017:06 R1*)

- Consider introducing requirements for safety harness or other restraint systems for all types of balloons in commercial passenger operations and clarifying the conditions in which the system is to be used. (*RL 2017:06 R2*)

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Circumstances

The intention of the flight was a hot air balloon flight experience with two passengers.

The preparations for the flight included load and navigation calculations, collection of weather information and a review for the passengers on safety during flight in a hot air balloon.

Weather information was obtained during the afternoon until 17:30 hrs by means of the Swedish Balloon Federation's member weather service, SMHI's overview chart for significant weather (SWC)[6] and the weather applications yr.no and WeatherPro. Weather information was thereafter obtained by means of yr.no and WeatherPro until just before the flight.

The weather forecasts showed that the wind would increase during the evening because of a cold front. The pilot intended to make a final assessment of the weather and the conditions for the flight at the lift-off site.

During the afternoon, the pilot and one of the passengers had a text message dialogue regarding the possibility of performing the flight. This dialogue indicates that the flight was a surprise for the other passenger and that it was desirable to perform the flight on this day since other proposed times were not suitable for various reasons. The dialogue further shows that the pilot was well aware of the forecast cold front and expressed this to be a factor that might make the flight impossible. It also indicates that the pilot received a positive response from one of the passengers when he declared that he was willing to make an attempt to perform the flight.

After having been at two potential lift-off sites, Pilängen Model Aircraft Field southwest of Örebro was chosen.

In addition to the pilot, ground crew from the company participated in support cars. The wind was probed using small pilot balloons in order to determine the wind at different heights. With the prevailing wind conditions, light winds from the west, a flight route was planned south of Lake Hjälmaren towards Stora Mellösa southeast of Örebro. The pilot assessed the conditions for flight to be favourable and lifted off at 20:07 hrs. The flight time was calculated to be one hour.

[6] SWC – Significant Weather Chart.

Figure 1. The actual hot air balloon Photo: Marcus Ewertsson.

1.1.2 Sequence of events

The flight was initially performed under favourable conditions at altitudes between 2 000 and 3 000 feet. At these altitudes, the wind speed and thus the balloon's speed was 20-25 km/h. The passengers showed great interest in the balloon's operation and learned, among other things, the function of the top vent.

After about 40 minutes' flight, those on board observed that fog was beginning to come in on the north side of Lake Hjälmaren and that waves were beginning to form on the lake.

Due to the observed weather changes, the pilot decided to immediately abort the flight and commenced a descent from 3 000 feet. When the balloon was approaching ground level and was at an altitude of 300 feet, the fog had come close. The pilot selected a suitable landing site, but before the landing could be commenced, the wind changed direction and strength, which made a landing at the selected site impossible. The pilot then selected a new landing site south of Lake Västra Kvismaren.

The pilot instructed the passengers regarding an appropriate position and placing in the basket before landing. In the final stage of the approach and at a height of 300 feet, the balloon unexpectedly climbed to 600 feet. The pilot counteracted this by opening the top vent, upon which the balloon began to descend again. According to the pilot, the equipment on his computer displayed a ground speed of 45 km/h (24 knots).

The touchdown was very hard and came to take place at an embankment 70 metres before the designated field. Both the rate of descent and the speed were high. All those on board lost their balance and fell over. In connection with this, the pilot, who had his hand on the handles for the burners, happened to inadvertently put the burners on full power. This contributed to the balloon climbing to a height of 30-50 metres. The pilot, who was shaken and had also lost his glasses at touchdown, had difficulties seeing and orienting himself. Shortly thereafter, the pilot nevertheless succeeded in shutting down the burners.

In order to prevent a new hard touchdown, the pilot reactivated the burners, but the second touchdown was also hard (see Figure 2). The balloon was then dragged by the wind at high speed along the ground with short airborne intervals. About 400 metres after the second touchdown, the pilot fell out of the balloon basket in conjunction with a hard ground contact.

The balloon then climbed to a height of 10-15 metres with only the two passengers on board. Since, during the flight, the passengers had learned that the red-and-white operating line controls the top vent, one of them pulled on the line so that the balloon descended towards the ground.

The passengers then decided to leave the balloon basket, which was still being dragged by the wind at high speed. The first passenger became caught for a short time between the basket and the ground. When the second passenger was leaving the basket, his foot became entangled in an operating line. Held fast by the line, the passenger was dragged behind the balloon at high speed, at times in the air and at times on the ground, for several hundred metres before the balloon drifted into a power line and stopped (see Figure 3).

At the power line was an excavator on which the passenger succeeded in securing the line. He then received help from an onrushing person to come loose from the line.

Figure 2. Ground tracks from the second touchdown.

Figure 3. The moment when the balloon envelope hit the power line. Photo: Emil Axelsson.

1.2 Injuries to persons

	Crew members	Passengers	Total on board	Others
Fatal	-	-	0	-
Serious	1	1	2	-
Minor	-	1	1	-
None	-	-	0	-
Total	1	2	3	-

1.3 Damage to aircraft

Substantially damaged.

1.4 Other damage

1.4.1 Environmental impact

Minor damage to crops and vegetation.

1.4.2 Other damage

The accident caused damage to a 10 kV power line that resulted in a power outage that lasted for two hours until 23:20 hrs. In addition to this, there was damage to several fences.

1.5 Personnel information

1.5.1 Pilot in command

The pilot in command was 31 years old and had a valid balloon pilot license with flight operational and medical eligibility.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	1	1	2	389
Actual type	1	1	2	84

Number of landings actual type previous 90 days: 2.
Type rating concluded on 23 October 2012.
Latest PC[7] conducted on 05 January 2016 on the type.

1.5.2 The pilot's duty schedule

The flight was the pilot's first and only flight of the day.

1.5.3 Other personnel affected

Three persons participated in the flight assignment as ground crew in two support cars.

[7] PC - Proficiency Check.

1.6 Aircraft information

1.6.1 Hot air balloon

TC-holder	Cameron Balloons Ltd
Model	Lindstrand LBL-120A
Serial number	1423
Year of manufacture	2012
Gross mass, kg	Max authorised take off mass 1 200, actual 710
Centre of gravity	Not applicable
Total flying time, hours	153
Flying time since latest in-spection, hours	30
Type of fuel uplifted before the occurrence	Propane

Burner	
TC-holder	Cameron Balloons Ltd
Burner type	LBL Jetstream II
Number of burner units	2
Total operating time, hours	153
Operating time since latest inspection, hours	30

Deferred remarks	None

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

1.6.2 The top vent

On the top of the balloon envelope there is an opening with a vent allowing for a controlled release of hot air. The vent is operated with a red-and-white line. The vent is used during flight to release hot air and thereby reduce the balloon's lift, and for deflating the balloon upon landing. The balloon had an extra system that allows for a rapid and complete deflation of the balloon upon landing. This system is controlled by a red line. The system can be reset with the red-and-white line.

1.6.3 The balloon's operation

A hot air balloon is controllable vertically in that the pilot can activate the burners and heat the balloon, which increases lift so that the balloon climbs. Opening the top vent releases hot air, upon which the balloon is cooled and descends. The pilot cannot directly operate the balloon in the horizontal plane since the balloon moves with the wind in the air mass it is in. However, the pilot can to some extent indirectly

steer the balloon horizontally by choosing altitudes with a different wind direction.

1.7 Meteorological information

1.7.1 Meteorological conditions

A sharp cold front, with risk of local thunderstorms south of the front, was moving south over Svealand during the afternoon and evening.

1.7.2 Meteorological forecasts

SMHI issues overview charts (SWC)[8] for significant weather conditions in Sweden and neighbouring countries, valid for a fixed time. Significant weather is according to the Chicago Convention Annex 3 defined as weather conditions encompassing for instance thunderstorms and turbulence. Such weather may be considered unsuitable conditions for hot air balloons.

The SWC issued on 10 May at 15:45 hrs that was valid for 20:00 hrs showed a sharp cold front that was moving south (see Figure 4).

[8] SWC – Significant Weather Chart.

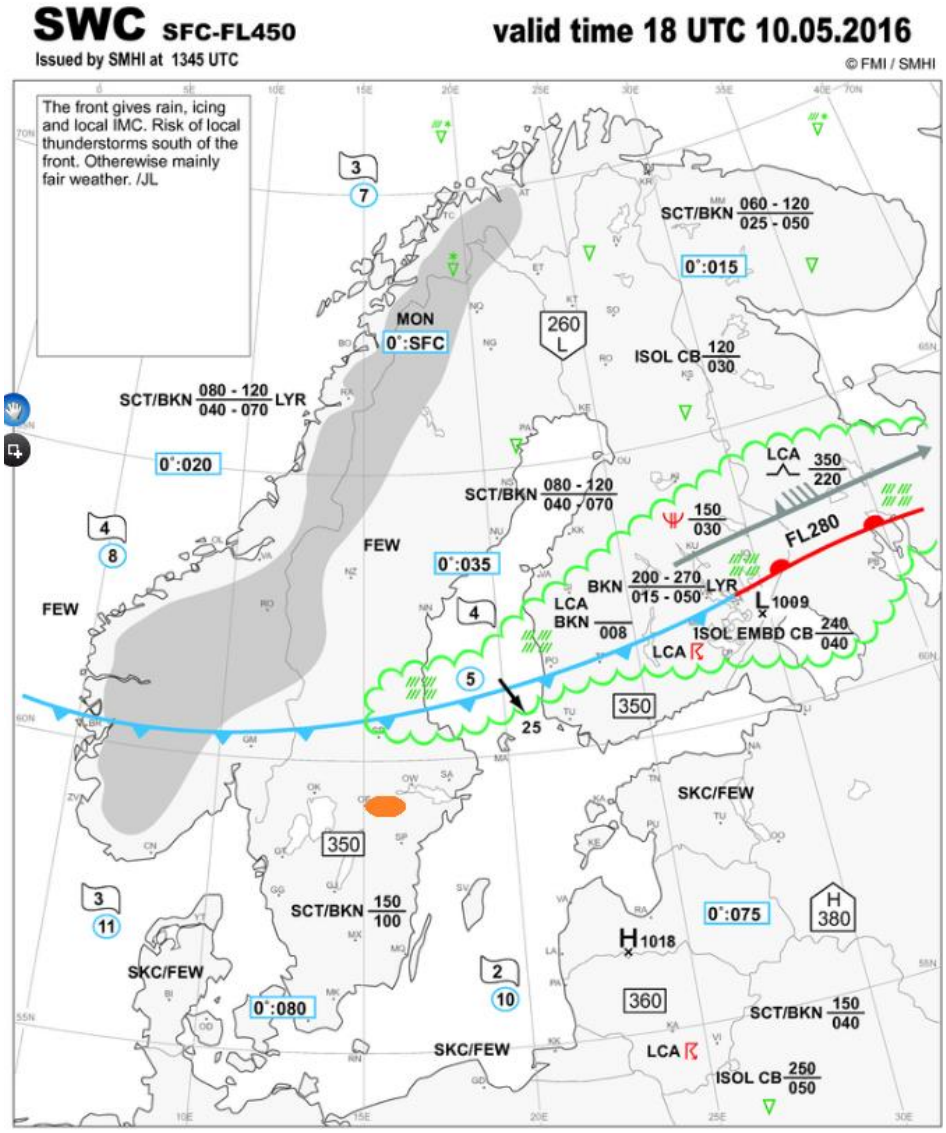

Figure 4. Printout of the SWC. Source: SMHI. The area of the flight is marked with an orange ellipse south of the cold front.

An amended SWC issued at 20:00 hrs and valid for the same time showed a trough line just north of the area of the accident with severe turbulence at low altitude (see Figure 5). A trough or a trough line is an elongated area with lower air pressure, characterized by thunderclouds. A trough line can move at speeds of twenty to sixty knots and lead to sudden and surprising weather conditions, such as from sunshine to rain showers and powerful, gusty winds in a very short time.

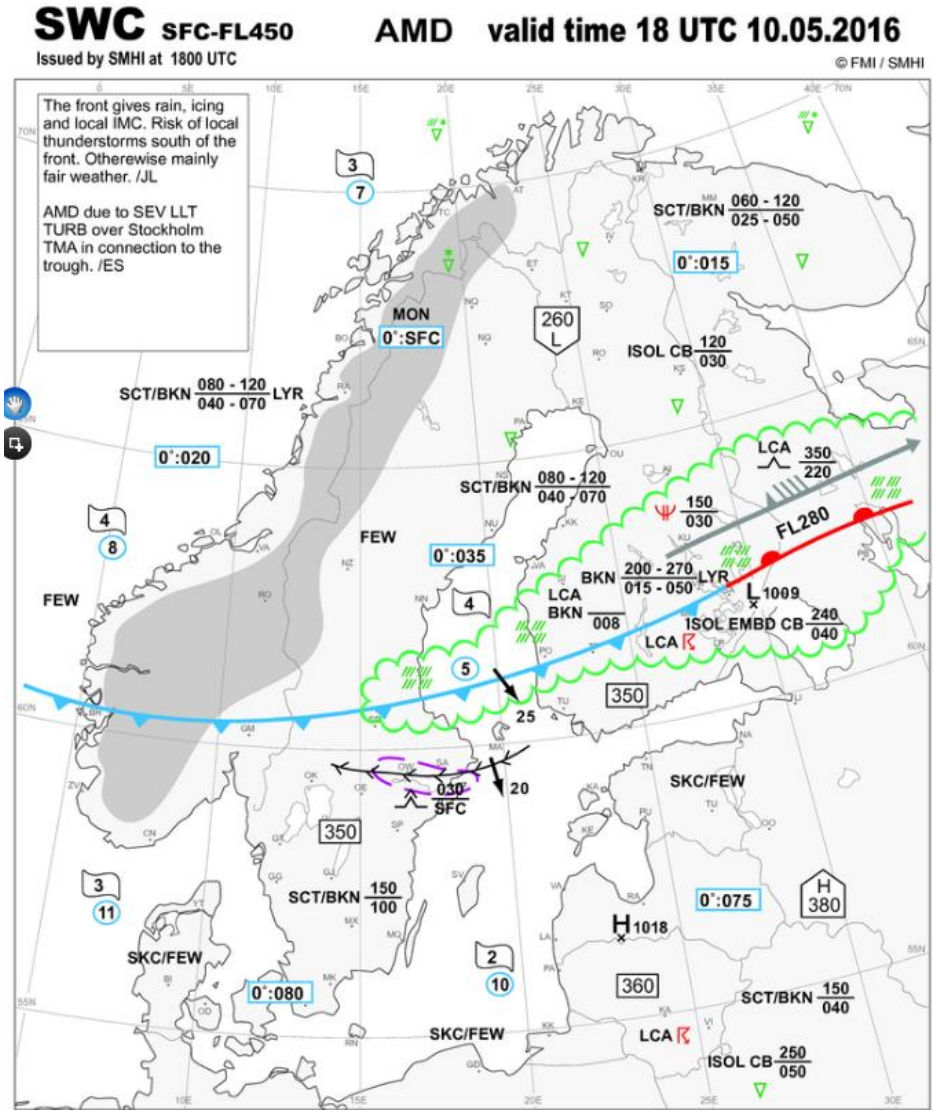

Figure 5. Printout of the SWC. Source: SMHI.

SMHI also issues aerodrome forecasts (TAF)[9] for the weather at about thirty aerodromes in Sweden. The aerodrome forecast for Örebro Airport issued on 10 May at 16:30 hrs stated that the wind from 17:00 hrs would be southwesterly 10 knots. Between 19:00 hrs and 21:00 hrs, the wind would then be northwesterly 7 knots. Between 22:00 hrs and 24:00 hrs, the wind would be northeasterly 10 knots with gusts up to 20 knots.

A later updated aerodrome forecast issued at 19:30 hrs stated that the wind would become northeasterly 10 knots with gusts up to 20 knots already from 21:00 hrs.

The wind forecast for Örebro on yr.no, available at 15:00 hrs, was as follows (the forecast is for a 10-minute average wind at a height of 10 metres):

[9] TAF – Terminal Aerodrome Forecast.

At 20:00 hrs wind northwest 5 m/s (10 knots)
At 21:00 hrs wind northwest 4 m/s (8 knots)
At 22:00 hrs wind northeast 9 m/s (18 knots)

Updated wind forecast on yr.no available at around 18:00 hrs:

At 20:00 hrs wind northwest 4 m/s (8 knots)
At 21:00 hrs wind northwest 3 m/s (6 knots)
At 22:00 hrs wind northeast 7 m/s (14 knots)

According to Yr, wind gusts are not presented on the website in Sweden. Furthermore, a forecast can in reality be updated later than the time that is stated.

The wind forecast for Örebro Airport according to information available via the Swedish Balloon Federation's member weather service and the application WeatherPro, issued at 15:00 hrs, was as follows (the wind is ground wind):

At 20:00 hrs wind west 6.3 knots, gusts 14.9 knots
At 21:00 hrs wind northwest 7.8 knots, gusts 16 knots

The wind forecast for Örebro Airport according to information available via the Swedish Balloon Federation's member weather service and the application WeatherPro, issued at 18:00 hrs:

At 20:00 hrs wind west 5.7 knots, gusts 14.5 knots
At 21:00 hrs wind northwest 7.5 knots, gusts 16.1 knots
At 22:00 hrs wind northeast 9.6 knots, gusts 18.8 knots

1.7.3 Meteorological conditions at the time of the accident

According to SMHI's analysis:

Wind: West 5 knots, at around 21:00 hrs rapid change to north-northeast 15-20 knots, gusty winds.
Visibility: More than 10 km.
Cloud: None below 5 000 feet.
Temp: +20-24ºC, behind the cold front approximately +15ºC.
Dewpoint: +1ºC, behind the cold front approximately +6ºC.
QNH: 1015 hPa, rising.

Measurements at Örebro Airport show that the wind turned quickly from west to northeast at 21:10 hrs (see Figure 6), at the same time as the wind speed increased to 25-30 knots in the gusts (see Figure 7).

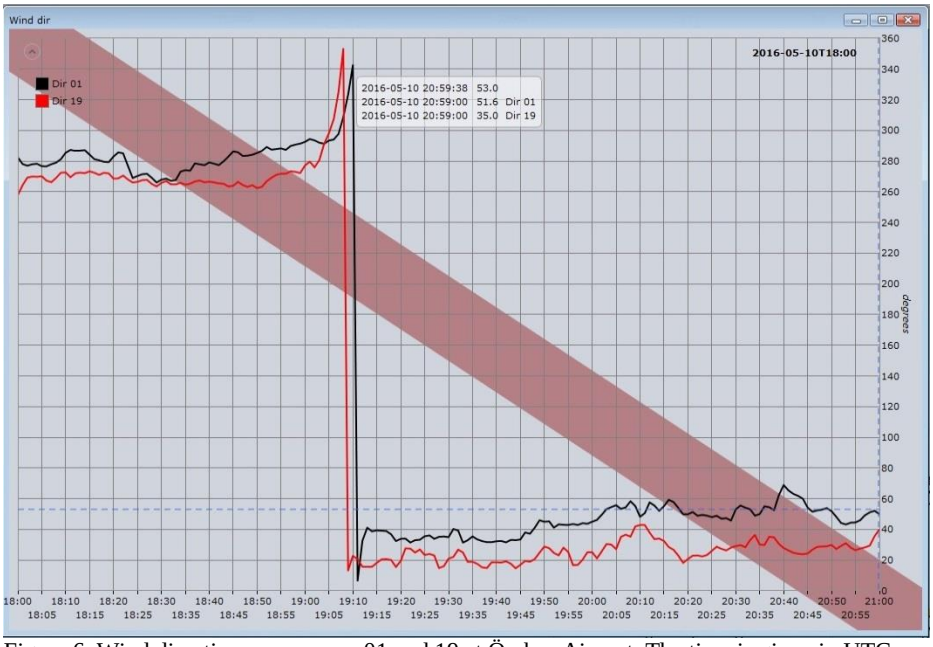

Figure 6. Wind direction on runways 01 and 19 at Örebro Airport. The time is given in UTC. The figure clearly shows how quickly the wind changed direction at the time of the accident Source: Örebro Airport.

Figure 7. Wind speed on runways 01 and 19 at Örebro Airport. The time is given in UTC. The figure shows how quickly the wind increased in strength at the time of the accident. Source: Örebro Airport.

1.7.4 Wind gradient

The wind's friction against the surface of the ground entails that the wind speed is lower closest to the ground, but increases with height. This effect (the wind gradient) varies with the wind strength and acts from the surface of the ground and up to an altitude of a few hundred metres. The wind gradient means that an air flow is formed over the balloon envelope. Due to the curved shape of the envelope, an area of low pressure is created over the top of the balloon envelope. This results in the creation of an additional aerodynamic lift that contributes to the balloon climbing.

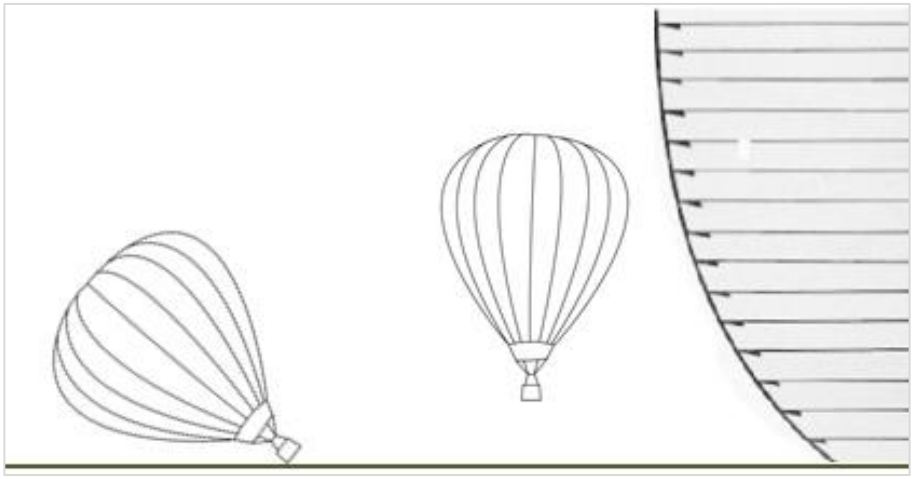

Figure 8. Sketch showing the principle of the wind gradient's effect on a balloon before and after landing.

1.8 Aids to navigation

On board the balloon was a laptop computer for navigation with installed software of the brand Windmaster.

1.9 Communications

The pilot had radio contact with the air traffic control at Örebro Airport.

In addition to the usual communication regarding clearances, etc. the pilot requested information about the wind and asked to be called if the wind increased markedly. At 21:09 hrs, air traffic control called the pilot without receiving any response. Then had the accident event already started.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The balloon was equipped with navigation equipment capable of recording parameters from a laptop computer with GPS to a server. The equipment fell out of the balloon in conjunction with the first touchdown. SHK has reviewed the navigation information. The balloon's route is shown in Figure 9.

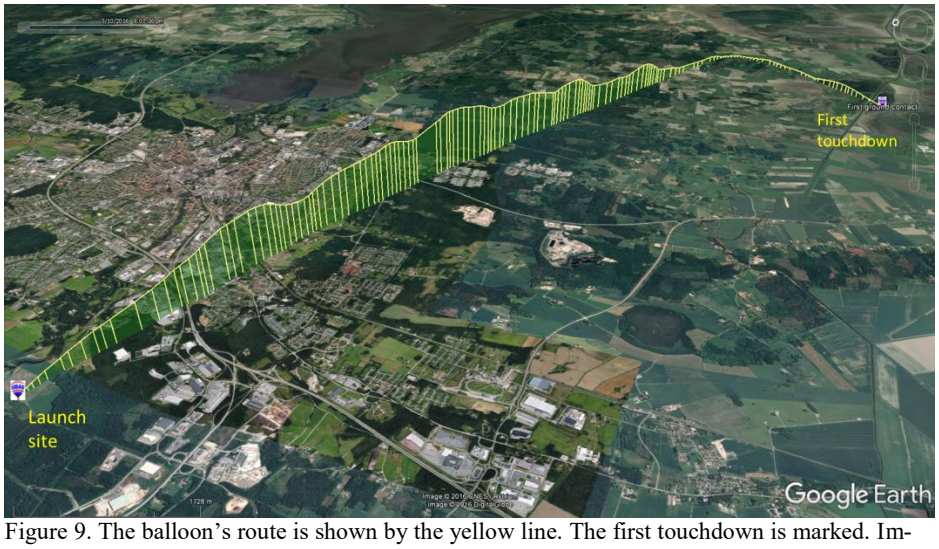

Figure 9. The balloon's route is shown by the yellow line. The first touchdown is marked. Image: Google Earth. Map data: © Lantmäteriet Ref no R61749-13002.

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

The first touchdown was made in the southern part of the Västra Kvismaren nature reserve. The balloon then continued in a southwesterly direction. A second touchdown was made after about 1 000 metres. The balloon was then dragged along the ground or through the air for a further 1 000 metres. It finally stopped at a power line near a residential building (see Figure 10). The area at the accident site mainly consisted of open fields and pastures.

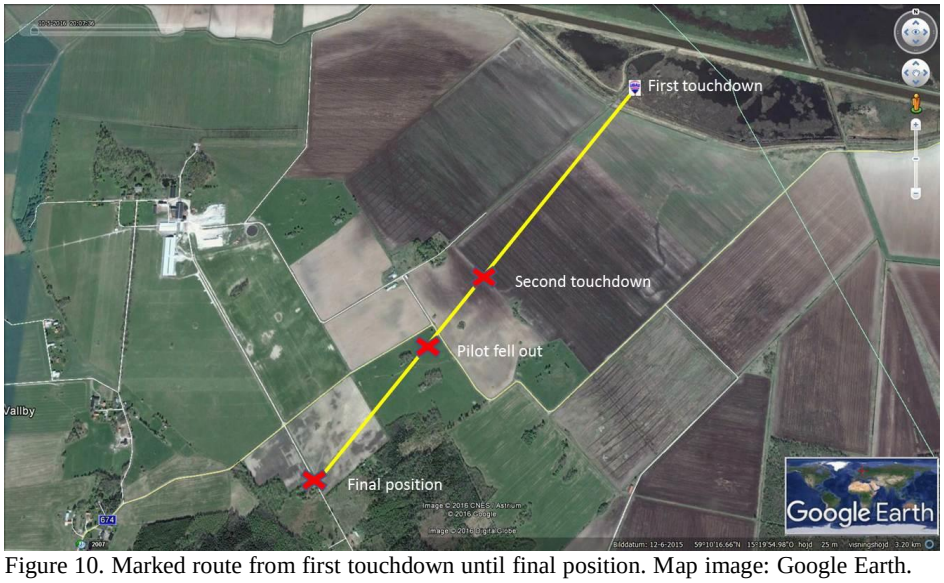

Figure 10. Marked route from first touchdown until final position. Map image: Google Earth. Map data: © Lantmäteriet Ref no R61749-13002.

1.12.2 Aircraft wreckage

The balloon was recovered during the evening and was transported to premises in Örebro where a technical inspection was performed. The inspection gave the following results:

- The balloon envelope sustained tears to several panels and burns to panels on the upper and lower parts of the envelope.
- The burns on the envelope's upper parts have probably been caused by arcing when the balloon hit the power line.
- The structure of the balloon basket sustained substantial damage.

1.13 Medical and pathological information

Nothing indicates that the mental and physical condition of the pilot was impaired before or during the flight.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Rescue operation

The first call to SOS Alarm (112) about the event was received at 21:14 hrs. Three ambulances were sent to the site.

The police and emergency services also participated in the rescue operation.

No emergency locator transmitter (ELT) was installed, nor is this a requirement for hot air balloons.

1.15.2 Position of and injury to those on board and use of safety belts

The space for the pilot and passengers consists of a basket, mainly made of rattan, in which those on board stand during flight.

The pilot and one of the passengers suffered serious injuries in the accident. The other passenger received minor injuries.

There were no safety belts. Nor is this a requirement. However, a safety harness for the pilot was installed. The harness was not used during the event. According to the pilot, there was no time to put it on.

Under Chapter 2, Section 31 of the Swedish Civil Aviation Authority's regulations (LFS 2007:48) on commercial air transport with manned hot air balloon, the pilot operating the balloon is to be anchored with a safety line when landing *"if the conditions so require"*.

This anchoring is to be executed in such a way that it does not obstruct the pilot's work.

The operator's operations manual states that there is to be a safety harness in the basket.

Neither the authority regulation nor the operations manual states in more detail the conditions in which the safety harness is to be used.

The Commission Regulation (EU) No 965/2012, which is scheduled to be introduced for commercial air transport with hot air balloons in 2018, states that balloons with a separate compartment for the commander shall be equipped with a restraint system for the commander. EASA rules will replace the national regulations.

According to EASA's proposal for new operational rules for balloons[10], a restraint system is prescribed for all operations, when the balloon is either equipped with a separate compartment for the pilot-in-command or when it is equipped with turning vents. For such balloons the pilot-in-command must wear the restrain system at least during landing.

1.16 Tests and research

None.

1.17 Organisational and management information

1.17.1 The operator

Ballongflyg i Väst AB had a valid licence for passenger flight operations issued by the Swedish Transport Agency. The last audit of the organisation was carried out on 16 March 2015.

The pilot had a valid contract as a pilot within the operator. The flight was ordered through Ballongflyg i Örebro, which is a sales company for Ballongflyg i Väst AB.

1.17.2 The operator's descriptions for weather information

According to the operator's operations manual, a preliminary weather forecast is obtained at 15:00 hrs, and at 16:00 hrs a message is to be given by telephone answering machine to passengers and personnel about the forthcoming flight. It also states that a new evaluation of the weather forecast is to be made one hour before the flight.

The operations manual states that sources of weather information can be:

- *SMHI Agricultural weather*
- *Low Level Forecast (LLF)*

[10] EASA Opinion No 01/2016 "Revision of the European operational rules for balloons"

- *Meteorologist direct (GBG)*
- *The website www.ballong.org – the Swedish Balloon Federation's member weather service*
- *Agricultural weather with radar images*
- *SMHI*
- *LFV – Flight planning centre*

1.17.3 Operational limitations for flight

The operator's operations manual, states the following operational limitations for flight:

Max lift-off wind ground:	*Recommendation 10 knots, based on local conditions.*
Max landing wind	*Recommendation 8 knots, based on local conditions.*

The flight manual for the balloon states the following:

The balloon should not be flown in meteorological conditions that give rise to unpredictable and gusty winds, which can cause an increase of 10 knots above average wind. The maximum ground wind speed for lift-off and landing is 15 knots.

1.18 Additional information

1.18.1 Regulations with requirements on the pilot's experience

Under Chapter 2, Section 66 of the Swedish Civil Aviation Authority's regulations (LFS 2007:48) on commercial air transport with manned hot air balloon, the Head of Flight Operations may not appoint a pilot as the commander on a balloon unless the pilot has in the preceding 90 days either performed at least 3 balloon flights as commander, of which at least one with the actual type, or undergone periodic flight training (PFT)[11].

1.18.2 Regulations on weather conditions

Under Chapter 2, Section 19 of the Swedish Civil Aviation Authority's regulations (LFS 2007:48) on commercial air transport in a manned hot air balloon, a flight may not be commenced "*until current weather reports, weather forecasts, personal observations, or a combination of these, show that the weather conditions on the route will be such that it is possible to perform the flight safely and with respect to applicable limitations in the flight manual, operations manual, BCL-T and to these regulations".*

EASA's Opinion No 01/2016 "Revision of the European operational rules for balloons" contains a proposal that the pilot-in-command shall

[11] PFT has subsequently changed designation to PC (Proficiency Check).

only commence or continue a VFR[12] flight if the latest available meteorological information indicates that the weather conditions along the route and at the intended destination at the time of use will be at or above the applicable VFR operating minima; and within the meteorological limitations specified in the AFM[13]. Before commencing the flight, the pilot-in-command shall be familiar with available meteorological and aeronautical information appropriate to the intended flight which includes a study of available current weather reports and forecasts and the planning of an alternative course of action to provide for the eventuality that the flight cannot be completed as planned.

1.19 Special methods of investigation

Not applicable.

2. ANALYSIS

2.1 Flight planning

2.1.1 Margins to forecasted significant aviation weather

The weather information that was obtained before the flight and until 17:30 hrs covered SMHI's overview chart of significant weather (SWC), the Swedish Balloon Federation's member weather service and the weather applications yr.no and WeatherPro. Thereafter the pilot only made use of the applications yr.no and WeatherPro.

SMHI's overview chart for significant weather conditions issued at 15:45 hrs showed that a sharp cold front that would pose a risk of thunderstorms moved south across Svealand during the afternoon and evening. The weather forecasts that the pilot used for flight planning indicated though only a moderate wind (6-8 knots) from the northwest up until 21:00 hrs. However, according to the forecasts, the wind would then change direction and increase in strength at 22:00 hrs. According to the forecast that was available at 15:00 hrs on the weather application yr.no, the wind at 22:00 hrs would increase to 18 knots. However, in the forecast that was available at 18:00 hrs, the wind strength was revised to 14 knots (see Section 1.7.2).

Since the pilot planned to land at approximately 21:00 hrs, the forecast weather conditions during the time of the planned flight may in principle be considered to be within the operator's limitations (10 knots max lift-off wind and 8 knots max landing wind). However, according to WeatherPro, there was a risk of wind gusts that were outside the balloon's operational limitations. However, locally at the lift-off site,

[12] VFR – Visual Flight Rules.
[13] AFM – Aircraft Flight Manual.

there was only a light westerly wind before lift-off (see Section 1.1.1). Against this background, the pilot cannot be deemed to have acted contrary to the operating limitations when he made the decision to perform the flight.

It is true, however, that weather forecasts are only approximate both for forecasted weather conditions as for the time of a change in weather. In view of the forecasts that the pilot used, the margin appears too small between the planned completion of the flight and the time at which there was reason to assume that the weather would deteriorate drastically with the risk of thunderstorms. However, there are no rules regarding time margins between scheduled flight and forecasted significant unsuitable aviation weather. Since it is not possible with a balloon to turn and fly towards better weather, the introduction of such rules could, in SHK's view, reduce the risk of accidents of this type.

2.1.2 Sources of information on aviation weather

An aerodrome forecast (TAF)[14] for Örebro Airport issued just over 30 minutes before lift-off stated that the wind would become northeasterly 10 knots with gusts up to 20 knots at the time of the planned landing. Such conditions are outside the operational limitations, both in the operator's operations manual and in the flight manual. That this weather deterioration would already occur from 21:00 hrs was, however, not apparent from either yr.no or WeatherPro.

An amended SWC also included a warning for severe turbulence at low altitude just north of the area of the accident. However, it was not issued until 20:00 hrs, i.e. only just before lift-off. The pilot had of this reason not taken this information into account.

The aerodrome forecast, which is part of SMHI's aviation weather service, was not used in the weather planning for the flight. Although weather information from sources other than SMHI's aviation weather service can be a complement, it cannot, in SHK's view, replace the aviation weather service when planning a flight. For example, the application yr.no does not report wind gusts, and its forecasts are sometimes updated with some delay.

2.1.3 External pressure to perform the flight

SHK has looked into the matter if the pilot may have been influenced by the passenger's wishes to perform the flight. However, the pilot has stated that he would never tamper with safety to be accommodating to passengers, because safety is of as equal importance for himself as for the passengers. He further stated that he has previously canceled a flight with the passengers due to poor weather conditions. According to the pilot, he would never carry out a flight on an uncertain weather forecast. Based on the weather forecasts the pilot had available, he deemed the weather to be fully flyable and that he could land safely

[14] TAF – Terminal Aerodrome Forecast.

before sunset. SHK has no reason to question the pilot's statement in this regard.

2.2 The landing

Just before the landing, the wind changed direction and strength, which meant that the landing could not be carried out at the site that had been selected. Instead, a new landing site was designated.

In the final stage of approach, when the altitude had become low and the balloon entered the wind gradient (see Section 1.7.4), an aerodynamic lift was created that caused the balloon to climb. The pilot counteracted this by opening the top vent and releasing hot air. When the balloon had climbed out of the wind gradient, the aerodynamic lift ceased. This resulted in a high rate of descent and a hard touchdown somewhat before the designated landing site.

Upon the touchdown, the balloon was slowed down, which caused a high rate of airflow over the balloon envelope that meant that the aerodynamic lift again increased. It is also probable that the balloon was not sufficiently deflated of hot air. In addition, the burners were inadvertently brought to full power in conjunction with the hard touchdown. All in all, this led to the balloon climbing up to a height of 30-50 metres. The pilot then closed the valves to the fuel tanks.

The second touchdown was also hard. After this, the balloon was dragged along the ground, alternating with shorter climbs up in the air. This was due to the fact that the system which enables a rapid deflation of the balloon's hot air was not activated, which in turn may be considered to be due to the fact that the pilot was thrown down in the balloon basket and was thereby shaken, and that he had lost his glasses.

When, after the second touchdown, the pilot fell out of the balloon basket, he consequently lost the ability to control the balloon.

2.3 Use of safety harness

The pilot was not using the safety harness that was in the basket in connection with the landing. This might have been due to the rapid sequence of event and that the pilot's attention instead being focused on performing such a safe landing as possible, and that he therefore - as he himself has stated - did not have time to put on the harness. Furthermore, a somewhat strange situation can arise if the pilot suddenly puts on a type of emergency equipment that is not available to the passengers, which in itself can have a deterring effect on the pilot.

As the regulations are designed, the requirement for a safety harness for the pilot appears to have been prioritised. However, there are no explicit rules regarding the conditions in which the pilot is to put on the safety harness. In light of this, SHK is of the opinion that the conditions in which the safety harness is to be used should be clarified.

Such clarification would make it easier for the pilot to assess when the harness should be used and would also make it easier to explain to the passengers why he or she is putting on the harness.

As previously stated, national regulations in the area will soon be replaced by common European rules developed by EASA. As the proposal looks like now, there will only be requirements for a restraint system for certain types of balloons. For these balloons, however, it is proposed that the restraint system is to be used during landing (see section 1.15.2). However, the actual type of balloon will not be covered by the requirements. According to EASA, it has been estimated that the risk is not as high that the pilot falls out of the basket in this type of balloon as in the case of balloons with a separate compartment for the pilot or balloons with turning vents. EASA further estimates that there may be some risks with a restraint system in a balloon without separate compartment for the pilot. However, this accident indicates that there is a risk that the pilot will fall out of the basket even in the actual type of balloon. SHK therefore believes that EASA should consider introducing restraint system requirements for all types of balloons in commercial air transport and to clarify in the regulations when it is to be used.

2.4 The pilot's qualification and training

The pilot's latest proficiency check (PC)[15] was carried out on 5 January 2016. Only two flights had been made in the previous 90 days before the accident. This means that the requirements of the Swedish Civil Aviation Authority's regulations (see Section 1.18.1) for the commander to have performed at least 3 balloon flights as commander or to have undergone periodic flight training (PC) in the preceding 90 days were not fulfilled. The pilot was thereby not formally qualified to perform the flight. However, nothing has emerged in the investigation to indicate that this should have had any influence on the event.

[15] PC - Proficiency Test.

3. CONCLUSIONS

3.1 Findings

a) The pilot was not qualified to perform the flight as commander.
b) The hot air balloon had a Certificate of Airworthiness and valid ARC.
c) When the decision was made to perform the flight, weather conditions were in principle within the operating limitations.
d) At the time of the accident, a powerful change in weather occurred in the matter of wind direction and wind speed. The latter meant that the weather conditions suddenly lay outside the operating limitations of the balloon.
e) The time margin between planned landing and unsuitable aviation weather was permitted, but too small.
f) The touchdowns in connection with the landing were very hard.
g) The system for a rapid deflation of the balloon's hot air was not activated in connection with the second touchdown.
h) The pilot's safety harness was not used.
i) The pilot fell out of the basket.
j) The balloon climbed with only the passengers on board.
k) One of the passengers pulled on the red-and-white operating line, which meant that the balloon again descended to the ground, after which the passengers left the basket.
l) One of the passengers became entangled in an operating line and was dragged behind the balloon by the foot for several hundred metres.
m) The balloon drifted into a power line and stopped.
n) Neither current regulations nor the operations manual provides more detailed guidance on the conditions in which the pilot's safety harness is to be used.
o) The balloon's envelope and basket sustained substantial damage.
p) The pilot and one of the passengers were seriously injured, while one passenger received minor injuries.

3.2 Causes

The accident was caused by the following factors:

- The flight was planned with a too small, albeit permitted, time margin to forecasted weather conditions that could impair a safe flight.

- A high speed and rate of descent during the landing caused the touchdowns to be very hard. In addition, after a hard ground contact, the pilot fell out of the basket and thereby lost the ability to control the balloon.

- The system for a rapid deflation of the balloon's hot air was not activated in connection with the second touchdown.

4. SAFETY RECOMMENDATIONS

The Swedish Civil Aviation Authority's regulations (LFS 2007:48) on commercial air transport with manned hot air balloon are currently applicable. New regulations for balloon flight, which will replace the national rules, are being drafted at EASA and are planned to be introduced in 2018. With reference to this, SHK does not deem it appropriate to recommend amendments to the current regulations but instead chooses to direct its recommendations to EASA.

The EASA is recommended to:

- Consider introducing time margins between planned landing time and significant weather conditions. (*RL 2017:06 R1*)

- Consider introducing requirements for safety harness or other restraint systems for all types of balloons in commercial passenger operations and clarifying the conditions in which the system is to be used. (*RL 2017:06 R2*)

The Swedish Accident Investigation Authority respectfully requests to receive, by **9 August 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,

Helene Arango Magnusson Ola Olsson