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Swiss Accident Investigation Board SAIB

Aviation Division

Final Report No. 2222 by the Swiss Accident Investigation Board SAIB

concerning the serious incident involving the DO328-100 aircraft, registration HB-AES

operated by SkyWork Airlines AG under flight number SRK 600

on 14 March 2012

20 km south of Zurich Airport

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Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass beim Start des Verkehrsflugzeuges das *forward outflow valve* nicht ganz geschlossen war und deshalb die Kabinendruckhöhe zu hohe Werte annahm.

Als direkte Ursache dieses schweren Vorfalls wurde ein falsch eingestelltes Bedienelement zur Steuerung des Kabinendrucksystems ermittelt, das von der Besatzung nicht bemerkt wurde.

Die folgenden Faktoren haben zur Entstehung des schweren Vorfalls beigetragen:

- Die Steuerung des *forward outflow valve*, die für den *manual mode* vorgesehen ist, wirkt auch im automatischen Betriebsmodus.
- Die Stellung des *forward outflow valve* wird der Besatzung nicht angezeigt.

Der folgende Faktor hat den schweren Vorfall zwar nicht direkt verursacht, wurde aber im Rahmen der Untersuchung als risikoreich erkannt (*factors to risk)*:

- Die Kommandantin und die Flugbegleiterin konnten sich am *interphone* nicht verständigen.

General information on this report

This report contains the Swiss Accident Investigation Board's (SAIB) conclusions on the circumstances and causes of the serious incident which is the subject of the investigation.

In accordance with Art 3.1 of the 10th edition, applicable from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

All information, unless otherwise indicated, relates to the time of the serious incident.

All times in this report, unless otherwise indicated, follow the coordinated universal time (UTC) format. At the time of the serious incident, Central European Time (CET) applied as local time (LT) in Switzerland. The relation between LT, CET and UTC is:
LT = CET = UTC + 1 hour.

Contents

Final Report

Synopsis

Owner	SG Equipment Finance Schweiz AD Gladbachstrasse 105, Postfach CH-8044 Zurich, Switzerland
Operator	SkyWork AG Airport Terminal North CH-3123 Belp, Switzerland
Manufacturer	Dornier GmbH
Aircraft type	DO328-100
Country of registration	Switzerland
Registration	HB-AES
Location	20 km south of Zurich Airport (LSZH), flight level 270
Date and time	14 March 2012, 15:15 UTC

Investigation

The serious incident occurred at 15:15 UTC. The incident was notified on the same day at 17:15 UTC and the Swiss Accident Investigation Board (SAIB) opened an inquiry at approximately 19:00 UTC. The SAIB informed the Federal Republic of Germany, as the country in which the aircraft was designed and produced, about the serious incident. The German Federal Bureau of Aircraft Accident Investigation (BFU) then appointed an authorised representative.

The present final report will be published by the SAIB.

Summary

On 14 March 2012 at 14:56 UTC the DO328-100 aircraft took off from Bern-Belp (LSZB) on a scheduled flight according to instrument flight rules to Vienna-Schwechat (LOWW). On board were three crew members and 17 passengers.

At 15:12:21 UTC, the aircraft reached its cruising altitude of flight level 270. Approximately one minute later, at 15:13:22 UTC, the CAB ALT caution message was displayed and at the same time an audible warning tone (triple chime) alerted the crew to this annunciation. At that moment the cabin altitude was 9500 ft and still rising. The crew donned oxygen masks and immediately initiated an emergency descent. At 15:14:55 UTC they declared an emergency and promptly received unrestricted clearance to descend from the air traffic control officer.

At this time the aircraft was 20 km south of Zurich. The crew decided to return to Bern-Belp at reduced speed. In accordance with the appropriate checklist the cabin altitude was then controlled manually until landing.

The flight attendant and the pilots could not understand each other via interphone. After the crew removed their oxygen masks and opened the cockpit door it was possible to communicate with the flight attendant.

Air traffic control supported the crew with flight level information and heading instructions, and the remainder of the flight was uneventful. The aircraft landed on runway 14 in Bern at 15:44 UTC.

Causes

The serious incident is attributable to the fact that when the commercial aircraft took off, the forward outflow valve was not completely closed and the cabin altitude became excessive.

The failure of the crew not to notice an incorrectly set operation element for controlling the cabin pressure control system was identified as a direct cause of this serious incident.

The following factors contributed to the occurrence of the serious incident:

- The control of the forward outflow valve, which is provided for in manual mode, also functions in automatic mode.
- The position of the forward outflow valve is not displayed to the crew.

Although the following factor did not directly cause the serious incident, in the context of the investigation it was identified as a risk factor:

- The commander and flight attendant could not understand each other via the interphone.

Safety recommendations

In the context of the investigation, one safety recommendation was issued.

According to the provisions of Annex 13 of the International Civil Aviation Organization (ICAO), all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which has to decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, any establishment and any individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

Swiss legislation provides for the following regulation regarding implementation in the Ordinance on the Investigation of Aircraft Accidents and Serious Incidents:

"Art. 32 Safety recommendations

[1] DETEC, on the basis of the safety recommendations in the SAIB reports and in the foreign reports, shall address implementation orders or recommendations to the FOCA.

[2] The FOCA shall inform DETEC periodically about the implementation of the orders or recommendations pronounced.

[3] DETEC shall inform the SAIB at least twice a year on the state of implementation by the FOCA."

1 Factual information

1.1 Pre-history and history of the flight

1.1.1 General

For the following description of the pre-history and history of the flight, the recordings of the radio communication, flight data recorder and radar data as well as the statements of the crew members and specialists at the relevant maintenance company and maintenance documentation were used. For the entire flight the commander was pilot flying (PF) and the copilot was pilot not flying (PNF).

The flight was conducted according to instrument flight rules (IFR). The flight was a scheduled flight.

1.1.2 Pre-history

Between 30 January 2012 and 13 March 2012 the HB-AES aircraft was on a heavy-maintenance visit (HMV) to a licensed maintenance company at Bern-Belp Airport. At this time the aircraft indicated 16 091:06 aircraft hours and 14 837 aircraft cycles. A fuselage leak test was performed during the HMV. This test was successful (cf. chapter 1.17.2.2).

The conclusion of the HMV work was confirmed with a work report, dated 13 March 2012, and the aircraft was released for operation with a 'certificate of release to service'. The only open point was entered in the deferred defect list (DDL) due to the fact that the corresponding material was not available: *"galley interphone protection cover missing".*

The operator then conducted a functional check flight following the HMV. The aircraft manufacturer does not stipulate such a test flight.

The test flight took off on 13 March 2012 at 13:50 UTC. As part of this, the following was tested with regard to the cabin pressure control system during take-off:

Pressurization	*Check Cabin ALT decreased*	*200 – 300 ft*
	Check Diff. Pressure increased	*+0.17 ± 0.03 PSI*

The measured values were within the prescribed tolerances.

After take-off, the aircraft climbed to flight level (FL) 150. After seven minutes, the aircraft descend to FL 120 and then climbed to FL 240. After another seven minutes, the aircraft continued climbing to FL 310. Four minutes later it began to descend to FL 200 and after another twelve minutes it began to descend to FL 150. One minute later the aircraft reached FL 130. The landing in Bern-Belp took place at 15:28 UTC. No further points were tested with explicit regard to the cabin pressure control system during the test flight. The system was operated in automatic mode and the analysis of the flight data indicates no warning was ever displayed with regard to the cabin pressure control system. The pilot raised four points during the test flight, but none of these were related to the pressurised cabin.

The aircraft was released for operation with a work order, dated 14 March 2012, at 16 092:44 aircraft hours and 14 838 aircraft cycles.

1.1.3 Flight preparation

Just after 14:00 UTC on 14 March 2012, the copilot of flight SRK 600 arrived at the aircraft and prepared it for the forthcoming flight. For this preparation, he worked through the appropriate 'flight deck preparation checklist'. This included amongst others checking whether the MAN CAB ALT knob on the pressurization panel was in the DN position (cf. figure 1, chapter 1.6.3.1).

1.1.4 History of the flight

At 14:57:02 UTC the DO328-100 aircraft, registration HB-AES, flight number SKR 600 and radio call sign *"Skyfox six zero zero"*, took off from runway 32 at Bern-Belp (LSZB) on a scheduled flight to Vienna-Schwechat (LOWW). On board were three crew members and 17 passengers.

The take-off took place normally and at 14:57:38 UTC, with a speed of 135 KIAS (knots indicated airspeed) and at an altitude of 2750 ft QNH, the flaps were retracted. The crew followed the assigned standard instrument departure route MEBOX 2B. At 14:57:56 UTC the autopilot was engaged and half a minute later the crew were instructed to change to the Bern Departure frequency. Shortly after this switchover they were cleared to FL 100 and instructed to turn right, with a direct heading to waypoint BERSU.

At 14:59:57 UTC the crew reported to the Zurich ACC West air traffic control officer (ATCO), who immediately issued them with a further clearance to climb to FL 120. At 15:01:24 UTC, SRK 600 passed flight level 100 at a speed of 178 KIAS and at approximately the same time the crew was working through the 'FL 100 checklist' (cf. chapter 1.17.1.2). According to the statement of the commander, during this check, the cabin altitude climbed through 3000 ft, whereas the value is normally approximately 1600 ft. However, she stated that the cabin rate had been normal. The copilot also stated that the cabin rate was approximately 50 ft/min and that the typical rate at that level was practically zero. He stated that he had not consciously perceived the cabin altitude.

A little later, at 15:02:28 UTC, the ATCO issued the crew clearance to FL 150 and at 15:03:54 UTC another clearance to FL 240 with the request to maintain a rate of climb of at least 1500 ft/min.

At 15:10:01 UTC, the crew, who had in the meantime switched to the 'Zurich M2' frequency, received clearance to FL 270 from the relevant ATCO. The aircraft was almost climbing to FL 240 at a speed of 160 KIAS. At 15:12:21 UTC, flight SRK 600 reached the cleared level of FL 270 and changed over to cruise flight.

The commander had just set cruise power when at 15:13:22 UTC the cockpit CAB ALT caution message was displayed and at the same time an audible warning tone (triple chime) alerted the crew to this annunciation. According to the statement of the commander, she noticed that the cabin altitude was 9600 ft and continuing to climb. The copilot looked to the commander, who at the same time called out *"cabin altitude"*. Both pilots immediately donned their oxygen masks. The copilot stated that he had needed a little longer for this than the commander and that in the meantime she had already turned on the seat belt sign and made the announcement *"cabin crew at station"*. The commander also stated that they had executed the by heart items from the respective emergency checklist and that she immediately initiated an emergency descent.

According to the records, the emergency descent was initiated at a speed of 192 KIAS at 15:14:14 UTC. The commander had selected FL 140 and asked the copilot to declare an emergency. At 15:14:55 UTC the copilot reported to the ATCO as follows: *"Skyfox six hundred, Mayday, Mayday, Mayday, we request to descend"*. The ATCO confirmed this message immediately and gave the crew unrestricted clearance to descend. In the meantime the commander had disengaged the autopilot. She ordered the copilot to work through the checklist and took over radio communications. She also stated that when she had consciously perceived the cabin altitude for the last time, it had indicated 10 500 ft.

The copilot stated that he had also noticed a cabin altitude of 11 500 feet and an amber[1] rate of climb, but that he no longer knew what the feet per minute rate was.

The flight attendant had been preparing the drinks trolley in the galley when the seat belt sign sounded and displayed. At the same time she also noticed a lateral movement of the aircraft and thought that something might be wrong. She immediately stowed the drinks trolley and at this moment heard the *"cabin crew at station"* announcement. According to the statement of the flight attendant, she did not find the emergency descent very steep and since oxygen masks were not deployed in the cabin she did not think that there had been decompression. She tried to contact the pilots via the interphone, but she could not understand them. According to her statement, she did however realise that the crew had donned oxygen masks.

During the emergency descent, the commander noticed that she could not make contact with the flight attendant. She later stated that she had heard the calm voice of the flight attendant via the passenger information system. As she knew that the flight attendant had plenty of experience, she was not concerned.

At 15:16:28, after their query regarding the minimum radar vectoring altitude, the ATCO offered the crew a flight altitude of FL 110 and at 15:17:25 UTC made the crew the following offer: *"Skyfox six hundred, if you like, left heading zero six zero will take you clear of uncontrolled airspace."* The crew immediately accepted this offer.

In the meantime, the copilot had begun working through the emergency checklist and had switched the cabin pressure control system to manual mode. According to his statement he manually controlled the cabin altitude during the remainder of the flight and then, during the approach, opened the outflow valve at approximately 5000 ft QNH, whereupon the rate of descent of the cabin altitude roughly corresponded to the rate of descent of the aircraft.

The commander had in the meantime made a situational assessment and decided to return to Bern-Belp. She had verified on the system displays that all the doors were closed and that there could not be a large leak. As she had no information about the condition of the aircraft fuselage, she also decided to reduce speed for the onward flight. At this time the aircraft was located approximately 20 km south-east of Zurich Airport with a speed reducing from 250 to approximately 220 KIAS. When the ATCO at 15:18:11 UTC asked: *"Skyfox six hundred, what would you like to do?"* the crew answered as follows: *"Proceed back Bern."* The ATCO then gave the following clearance at 15:18:26 UTC: *"Alright, Skyfox six hundred, continue left, left turn direct to ROTOS, follow the two mike."* Shortly before, the crew had engaged the autopilot and confirmed this clearance, whereupon the ATCO instructed the crew to maintain FL 110.

In the meantime the copilot had, according to his statement, noticed Zurich below and briefly wondered why they were not landing at Zurich Airport. However, he then said [translated from German]: *"As everything appeared to be under control, no vibrations or anything, I believed the decision to fly to Bern was appropriate."*

At 15:19:25 UTC, the ATCO asked the crew the following question: *"Skyfox six hundred, you still squawk mayday, ah or, ah, normal ops now?"* to which the crew immediately replied: *"Normal operation, Skyfox six hundred."* At this time, the aircraft was at FL 110 with a speed of 218 KIAS.

[1] Up to a rate of climb of ± 1000 ft/min this is displayed in white, between ± 1000 and 2500 ft/min it is displayed in amber and over ± 2500 ft/min it is red (for the location of the display cf. figure 2, chapter 1.6.3.1).

A little later, the crew was instructed to change to the Zurich Departure frequency. When the ATCO asked what flight level the crew wanted, they replied FL 70. They then received clearance to FL 90. At 15:20:55 UTC, the ATCO asked the following question: *"Skyfox six hundred, confirm, you're returning towards ROTOS?"* The crew answered this question in the affirmative and received further clearance to FL 70.

At 15:23:34 UTC the crew asked the ATCO: *"How many miles to expect for landing?"* to which the ATCO responded with the following enquiry: *"You're going back to Berne? Is that correct? And that's six zero miles to Berne."* The crew thanked them for this information and at 15:23:45 UTC the ATCO asked the following question: *"And, you have any other problems? Zurich would be an option as well, that's twenty five miles."* The crew replied: *"That's ok for the time. Berne is fine."* The ATCO then continued to give heading instructions on the basis of different airspace and at 15:26:05 UTC made amongst others the following comment: *"...and if there is anything, if I can support for you, just tell me."* The crew thanked him and stated that at the moment everything was alright.

As she could not communicate with the crew in the cockpit, the flight attendant in the cabin had, in the meantime, made her own situational assessment and told the passengers to put their trays on the floor, slide them under the seat in front and to fold away their tables. She had also asked the passengers to fasten their seatbelts tightly. As she did not know what type of landing to expect, she also showed the passengers the 'brace for impact position' for landing. She also informed them that the pilots were still busy and would report later.

A little later, she noticed that the cockpit door was opened and the pilots had taken off their oxygen masks. The commander then informed the flight attendant of the decompression that had taken place and the forthcoming normal landing in Bern. The flight attendant passed this information on to the passengers.

The remainder of the flight was uneventful and the crew landed the HB-AES aircraft on runway 14 in Bern-Belp at 15:44 UTC.

1.1.5 Location of the serious incident

Approximately 20 km south of Zurich Airport, flight level 270.

1.2 Injuries to persons

1.2.1 Injuries to persons

Injuries	Crew	Passengers	Total number of occupants	Others
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	3	17	20	Not applicable
Total	3	17	20	0

1.2.2 Nationality of the occupants of the aircraft

The crew consisted of two cockpit crew and a flight attendant, all Swiss citizens.

Because passengers did not have to specify their nationality at the time of booking, the operator could not provide any details in this regard. It is only known that

15 passengers gave their place of residence as Switzerland and two gave their place of residence as Austria.

1.3 Damage to aircraft

The aircraft was not damaged.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Commander

Person	Swiss citizen, born 1972
Licence	Airline transport pilot licence aeroplane (ATPL(A)) according to Joint Aviation Requirements (JAR), first issued by the Federal Office of Civil Aviation (FOCA) on 16 April 2004
Ratings	Type rating DO328-100 PIC (as pilot in command), valid till 27 March 2013 Class rating for single-engine piston aircraft (SEP), valid till 30 November 2012 Language proficiency: English Level 4, valid till 30 November 2013 Night flying NIT(A)
Instrument rating	Instrument rating aeroplane IR(A) Category II instrument approaches on DO328-100, valid till 27 March 2013
Last proficiency check	Line check on 29 January 2012 Operational proficiency check (OPC) on 22 September 2011
Medical fitness certificate	Class 1 with restrictions (VDL: shall wear corrective lenses) Valid from 15 June 2011 till 28 June 2012
Last medical examination	15 June 2011

1.5.1.1.1 Flying experience

Total	4011 hours
on the type involved in the incident	535 hours
during the last 90 days	139 hours
of which on the type involved in the incident	139 hours
as commander	1027 hours

1.5.1.1.2 Crew duty times

Start of duty in the 48 hours before the serious incident	12 March 2012, 09:15 UTC 13 March 2012, office duty 14 March 2012, 13:25 UTC
End of duty in the 48 hours before the serious incident	12 March 2012, 20:37 UTC 13 March 2012, office duty
Flight duty times in the 48 hours before the serious incident	12 March 2012, 11:22 hours 13 March 2012, office duty
Rest times in the 48 hours before the serious incident	More than 24 hours
Flight duty time at the time of the serious incident	1:31 hours

1.5.1.2 Copilot

Person	Swiss citizen, born 1981
Licence	Commercial pilot licence aeroplane – CPL(A)) according to Joint Aviation Requirements (JAR), first issued by the FOCA on 28 May 2010, valid till 22 August 2016.
Ratings	Type rating DO328-100 as copilot, valid till 6 August 2012 Class rating for multi-engine piston aircraft (MEP), valid till 13 April 2012 Class rating for single-engine piston aircraft (SEP), valid till 20 August 2013 Language proficiency: English Level 4, valid till 20 August 2014 Night flying (NIT)
Additional ratings	MCC Course ATP Theory according to JAR-FCL 1
Instrument rating	Instrument rating aeroplane IR(A) Category II instrument approaches on DO328-100, valid till 06 August 2012
Last proficiency check	Simulator check on 10 February 2012
Medical fitness certificate	Class 1/2 with restrictions (RXO: requires specialist ophthalmological examination), VDL (shall wear corrective lenses) Valid till 29 August 2012
Last medical examination	26 July 2011

1.5.1.2.1 Flying experience

Total	9345:19 hours
on the type involved in the incident	349:19 hours

during the last 90 days	180:33 hours
of which on the type involved in the incident	180:33 hours

1.5.1.2.2 Crew duty times

Start of duty in the 48 hours before the serious incident	12 March 2012, off duty 13 March 2012, off duty 14 March 2012, 13:02 UTC
End of duty in the 48 hours before the serious incident	12 March 2012, off duty 13 March 2012, off duty
Flight duty times in the 48 hours before the serious incident	12 March 2012, 0 hours 13 March 2012, 0 hours
Rest times in the 48 hours before the serious incident	More than 24 hours
Flight duty time at the time of the serious incident	1:54 hours

The copilot had a so-called standby duty from 04:00 UTC to 16:00 UTC on 14 March 2012. In accordance with the operational manual (OM) A of the operator this means that the crew member is not definitively deployed, but should be ready on-demand for deployment over a period of time (in the present case from 04:00 UTC to 16:00 UTC). OM A Chapter 7.1.12: *"A defined period of time during which a crew member has not been assigned to a specific flight duty, but is required to be continuously contactable by phone or other means."*

At 13:02 UTC the copilot was summoned by phone to fly to Vienna-Schwechat.

1.5.1.3 Flight attendant

Person	Swiss citizen, born 1966
Last proficiency check	Line check cabin crew Dornier 328 on 10 November 2011 Line check cabin crew Dash 8-Q400 on 4 March 2012
Medical fitness certificate	Issued by the FOCA in accordance with AMC OPS 1.995, regulation (EEC) no. 3922/91
Last medical examination	10 August 2011

1.6 Aircraft information

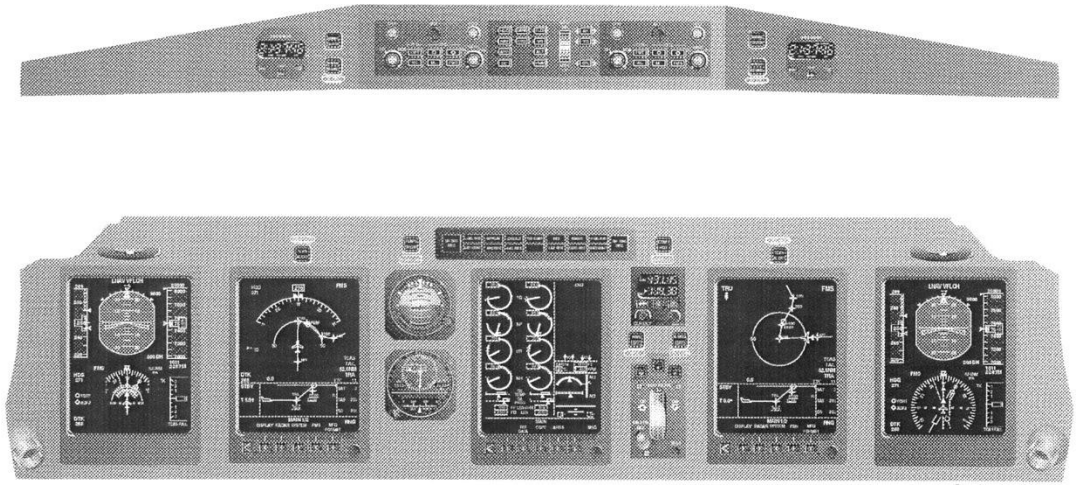
1.6.1 General information

Registration	HB-AES
Aircraft type	DO328-100
Characteristics	Twin-engined regional aircraft with turbo-prop propulsion, constructed as a cantilever high-wing monoplane in all-metal construction with retractable landing gear in nosewheel configuration

Manufacturer	Dornier GmbH
Year of manufacture	1995
Serial number	3021
Owner	SG Equipment Finance Schweiz AD Gladbachstrasse 105, Postfach CH-8044 Zurich, Switzerland
Operator	SkyWork AG Airport Terminal North CH-3123 Belp, Switzerland
Engines	2 Pratt & Whitney PW119B LH: S/N PCE-116054 RH: S/N PCE-116056
Propeller	2 Hartzell HD-E6C-3B LH: S/N HL-48 RH: S/N HL-319
Operating hours airframe	16 094 hours / 14 838 cycles
Max. permitted masses	Max. permitted take-off mass 13 990 kg Max. permitted landing mass 13 230 kg
Mass and centre of gravity	The mass of the aircraft at the time of departure was 12 948 kg. Both the mass and centre of gravity were within the permitted limits according to the aircraft flight manual (AFM).
Maintenance	The last scheduled maintenance took place from 30 January 2012 to 13 March 2012 after 16 091 hours.
Technical limitations	The following point was entered in the deferred defect list (DDL), dated 13 March 2012: *"Galley interphone protection cover missing. Part not available."*
Permitted fuel grade	JET A1 kerosene
Registration certificate	No. 3, issued by the FOCA on 17 April 2007
Airworthiness certificate	Issued by the FOCA on 20 April 2007, valid till revocation by the competent authority of the state of registration.
Certification	Commercial
Types of use	VFR day / VFR night IFR Category I / IFR Category II B-RNAV (RNP 5)

1.6.2 Cockpit layout

The basic cockpit layout is as follows:



PFD MFD EICAS MFD PFD

The cockpit layout mainly includes five displays, two primary flight displays (PFD), two multi function displays (MFD) and in the centre the display for the "electronic indication, caution and advisory system" (EICAS).

The two PFD are primarily used for indicating the attitude, altitude, airspeed and heading.

The two MFD are primarily used as navigation displays (ND) for the presentation of information from the navigation database and as flight management and flight planning displays. In addition a wide range of additional information can be displayed, e.g. traffic displays, weather radar and terrain.

The two MFD can however also be used to display selective selectable system pages (SP). Each system page also displays system status messages. The SP relevant for the present case are the following:

- ECS (Environmental Control System)
- CPCS/OXY (Cabin Pressurization and Control System / Oxygen System)
- DOORS (Doors)

The EICAS display primarily shows engine data. The right upper half of the display is kept free to show so-called: "caution and advisory system (CAS) field messages" that should make the crew aware of anomalies.

1.6.3 Cabin pressure system

1.6.3.1 General

The pressurization control system is responsible for maintaining a cabin altitude that is preselected by the cockpit crew. The system can be operated in automatic or manual mode.

The pressurization control system is usually operated in automatic mode. Manual mode serves as back-up. The operating elements for the system are fitted on the pressurization control panel as follows:

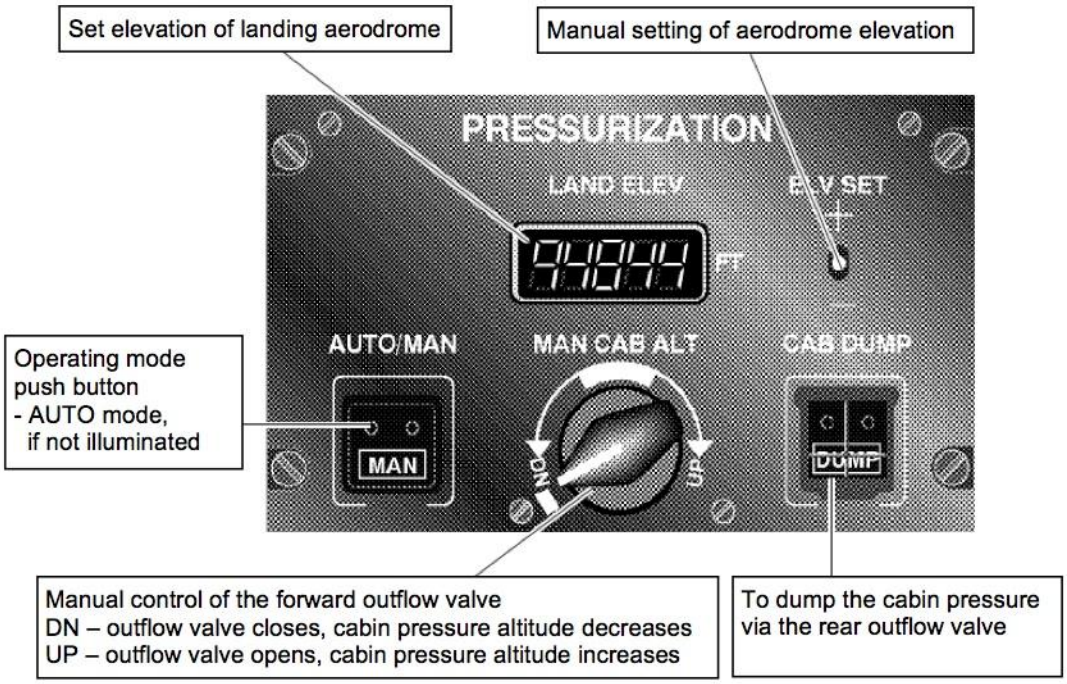


Figure 1: Pressurization control panel

The passenger cabin and the cockpit are provided with compressed air via the environmental control system (ECS) packs. The pressure in the aircraft can be regulated by opening and closing the so-called outflow valves. If an outflow valve is moved towards the closed position, the pressure increases and with it the cabin altitude decreases. If an outflow valve is opened, the cabin altitude rises.

The aircraft is equipped with two outflow valves. The rear valve is located in the rear bulkhead in the tail. In automatic mode this is controlled via the cabin pressure control system (CPCS). It is possible to switch to automatic mode on the pressurization control panel. The selected type of operation is confirmed via the AUTO display on the CPCS/OXY system page. The same page displays AUTO CTRL FAIL if there is an error. If the push button is used to select manual mode, the rear outflow valve closes.

The forward outflow valve is located in the forward bulkhead over the nosewheel. It can be opened and closed using the MAN CAB ALT control knob on the pressurization control panel and operates independently of the position of the AUTO/MAN push button. It is therefore important that the control knob is fully in the DN position (white mark) when in automatic mode.

The pneumatic valve is operated by engine bleed air and its position is therefore dependent on engine rpm. In the cockpit there is no explicit display for the position of the forward outflow valve. However, the parameters that are influenced, such as cabin altitude, differential pressure and cabin rate, are displayed as follows on the CPCS/OXY page:

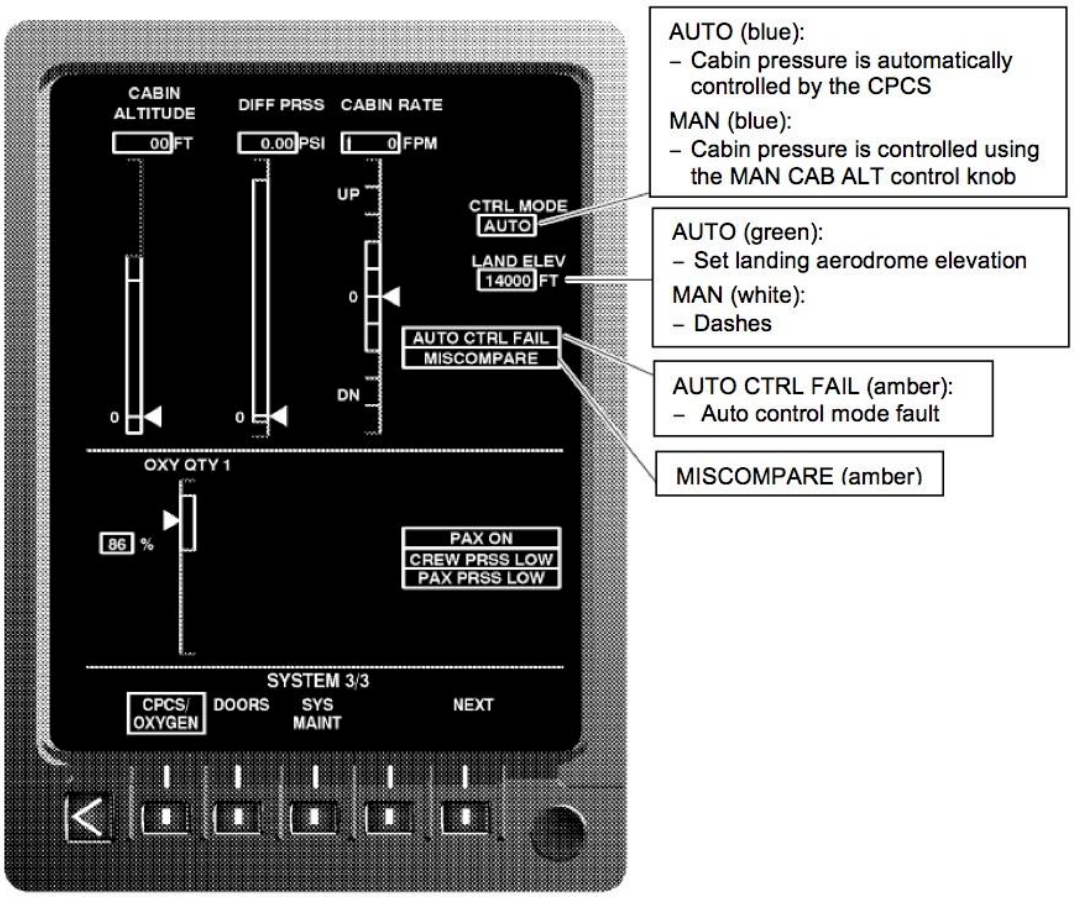
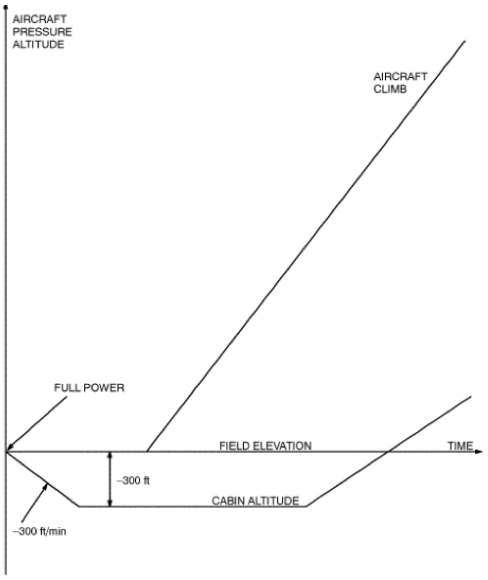


Figure 2: System page: CPCS / OXYGEN

1.6.3.2 Automatic mode

In automatic mode the cabin pressure control system (CPCS) controls the cabin pressure. When setting take-off power, a pre-pressurization phase occurs. This increases the differential pressure in the cabin until a cabin altitude has been reached that is 300 ft lower than the elevation of the take-off aerodrome (cf. figure 3). Once the aircraft has taken off and is in the air, the take-off sequence begins and the differential pressure is increased while the cabin altitude remains the same. The cabin altitude only begins to rise when the aircraft reaches an altitude of approximately 10 000 ft, but latest 10 minutes after take off. There is then an automatic switchover from take-off sequence to cruise mode and the cabin altitude increases at a rate of 450 ft/min, whereby the CPCS ensures that the value of 550 ft/min is not exceeded. The pressure gradient is controlled in such a way that the maximum differential pressure of 6.75 psi is reached at an altitude of 31 000 ft. This corresponds to a cabin altitude of 8000 ft (2438 m). At an altitude of 25 000 ft and a differential pressure of 6.62 psi, the cabin altitude reaches 5325 ft (1623 m).



PRESSUIZATION SCHEDULE		
PRESSURE ALTITUDE	CABIN ALTITUDE	DIFFERENTIAL PRESSURE
5000 feet	0 feet	2.47 PSI
10,000 feet	1,000 feet	4.06 PSI
15,000 feet	2100 feet	5.32 PSI
20,000 feet	3400 feet	6.22 PSI
25,000 feet	5300 feet	6.64 PSI
30,000 feet	7600 feet	6.72 PSI
31,000 feet	8000 feet	6.75 PSI

Differential pressure and cabin altitude gradients according to CPCS AUTO FAIL checklist for manual operation of cabin altitude. These correspond to the automatic mode history.

Figure 3: Pre-pressurization phase and take-off sequence

Before descending, the elevation of the landing aerodrome must be set using the ELV SET switch on the pressurization control panel. Before taking-off, the take-off aerodrome elevation is set in order to be prepared for a possible relanding after take off. The set altitude is displayed on the CPCS/OXY system page.

1.6.3.3 Manual mode

Manual mode is completely independent of automatic mode. In this mode the crew must set the cabin rate and the cabin altitude manually using the MAN CAB ALT control knob on the pressurization control panel. In doing so the parameters on the CPCS/OXY system page must be monitored. When the control knob is in the full UP position the cabin rate reaches 2500 ft/min. In the full DN position the cabin rate reaches -1500 ft/min. These values are dependent on the air supply to the ECS and the differential pressure. Both the automatic and the manual system have pneumatically operated safety systems. These limit the differential pressure and cabin altitude as follows:

Positive differential pressure Δp	7.0 ± 0.1 PSI
Negative differential pressure Δp	- 0.3 PSI
Cabin altitude	14 500 ft (± 500 ft)

1.6.3.4 Dump function

The dump function uses both the pneumatic forward outflow valve as well as the electro-pneumatic rear outflow valve.

- The forward pneumatic outflow valve can be opened using the MAN CAB ALT control knob.
- The electro-pneumatic rear outflow valve can be opened using the CAB DUMP button on the pressurization control panel.

Both dump functions can be activated independently of the current operating mode. In an emergency situation, both outflow valves can be opened simultaneously.

1.7 Meteorological information

1.7.1 General meteorological situation

Switzerland lay on the edge of an area of high pressure centred over the southern North Sea. At high altitude, a ridge extended from Spain to South England. Widespread sinking air led to cloudless skies over Switzerland.

1.7.2 Weather south of Dübendorf at the time of the serious incident

The weather was sunny and the visibility excellent. On the Jungfraujoch, the visibility at 12:00 and 18:00 UTC was specified as being over 70 km.

Weather/cloud	No cloud
Visibility	Over 70 km
Wind	From 005° at 35 kt
Temperature/dewpoint	-41 °C / -50 °C
Atmospheric pressure QNH	1026 hPa
Hazards	None

At the time of landing, the visibility in Bern-Belp was over 10 km. There was a north-westerly wind at 7 knots. The temperature and dewpoint were 18 °C and 3 °C, respectively.

1.7.3 Astronomical information

Position of the sun	Azimuth: 240°	Elevation: 22°
Lighting conditions	Afternoon	

1.8 Aids to navigation

There is one non-directional beacon (NDB) available for approaches on runway 14/32 at Bern-Belp Airport: Bern (BER). A category I instrument landing system is installed on runway 14.

1.9 Communications

Radiocommunication between the pilots and ATC took place correctly and without difficulties.

There were indications of communication problems between the cockpit and cabin via the interphone. The flight attendant did not understand the commander and therefore informed the passengers on the basis of her own situational assessment.

1.10 Aerodrome information

1.10.1 General

Bern-Belp Airport is located 9 km south-east of the Swiss federal state capital of Bern. The airport reference point (ARP) has the coordinates N 46° 54‘ 44“ / E 007° 29‘ 57”.

The reference elevation of the airport is 1673 ft AMSL and the reference temperature is 23.5 °C.

The runways at Bern-Belp Airport have the following dimensions:

Runway	Dimensions	Elevation of runway thresholds
14/32	1730 x 30 m	1668/1675 ft AMSL
14R/32L (grass runway)	650 x 30 m	

Runway 14 has an offset threshold and the available landing distance is 1530 m.

At the time of the serious incident, no restrictions had been published for Bern-Belp Airport that were relevant to flight SRK 600.

1.10.2 Runway equipment

Bern-Belp Airport has a hard-surface runway (14/32) and to the south-west, a parallel grass runway (14R/32L).

Runway 14 is equipped with an instrument landing system (ILS) with distance measuring equipment (DME). The instrument landing system is classified as Category 1 because it features aspects including a glide slope of 4°.

On runway 32 it is only possible to conduct non-precision approaches, in this case circling approaches.

1.10.3 Rescue and fire-fighting services

Bern-Belp Airport is equipped with Category 5 fire-fighting resources for scheduled traffic and Category 4 resources for other traffic. A higher category is available for commercial traffic upon request within three hours of the planned arrival/departure.

1.11 Flight recorders

1.11.1 Flight data recorder

1.11.1.1 General information

Type	F1000
Manufacturer	Fairchild
Serial number	Serial number 2163; part number S800-2000-00
Number of parameters	44
Recording medium	Solid state memory
Duration of recording	100 hours

The flight data recorder data was recorded in full and could be read. Neither the cabin altitude nor the cabin differential pressure were recorded. It is therefore not possible to make accurate statements about the behaviour of these two parameters during the flight.

1.11.2 Cockpit voice recorder

As the circuit breaker (CB) for the cockpit voice recorder (CVR) was not pulled after the flight, the recordings of the flight had already been overwritten and were no longer available to the investigation.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

There are no indications of the pilots suffering health problems during the flight.

1.14 Fire

Not applicable.

1.15 Survival aspects

According to the design regulations for commercial aircraft (FAR 25.841) the oxygen supply must be designed so that a warning is displayed at a cabin altitude in excess of 10 000 ft. This is to allow the crew to take measures to prevent the cabin altitude from rising further. For this purpose, the crew must don oxygen masks, so they can work without restriction, even if the cabin altitude increases further. Due to the aforementioned design regulations, the occupants of the aircraft may not be exposed to cabin altitudes in excess of 15 000 ft. To prevent incapacitation, oxygen masks are made available to the passengers and cabin crew. These are usually deployed automatically from the ceiling above the passenger seats at a cabin altitude of 13 500 ft. This oxygen supply must be guaranteed at least for 15 minutes, since it is assumed that during this time it is possible for the crew to bring the cabin altitude to a level that is not harmful to humans even without supplementary oxygen.

In the serious incident under investigation, the crew immediately donned their oxygen masks when the caution message was displayed and the emergency descent that they initiated immediately prevented the cabin altitude exceeding the threshold at which the oxygen masks are automatically deployed. There was therefore at no risk of the occupants being affected by an insufficient supply of oxygen at any time.

1.16 Tests and research

Not applicable.

1.17 Organisational and management information

1.17.1 Operator

1.17.1.1 General

The operator Sky Work Airlines AG was founded in 2004 as a subsidiary of Skywork AG. It is certified and authorised for commercial air transport by the Federal Office of Civil Aviation under air operator certificate (AOC) number 1039, issued on 10 November 2005. In autumn 2010, the operator was reorganised; in 2011, the operator transported 87 000 passengers. At the time of the serious incident the fleet consisted of three turboprop Dash-8 Q400 aircraft and four DO328 aircraft, including the one involved in the serious incident, HB-AES.

1.17.1.2 Checklists

The operations manuals (OM) A and B stipulate which procedures the crew must adhere to when operating the aircraft. The relevant checklists stipulate amongst others the necessary manipulations in terms of system verification and system operation. The checklist also stipulates which points must be processed by which pilot. Key:

"CM1, flight crew member no 1 seated in the LH seat.

CM2, flight crew member no 2 seated in the RH seat.

B/BP *Both, both flight crew members shall perform an action.*

PF *Pilot flying.*

PM *Pilot not flying, assisting pilot.*

* *only for aircraft equipped with ground spoiler."*

The following sets out to highlight only those points that were of importance in relation to the serious incident.

Chapter 2.5.2.1 of the OM B, *"EXPANDED - FLIGHT DECK PREPARATION CHECKLIST",* stipulates the following for the preparation of the aircraft with respect to cabin pressure under item 15:

"PRESSURIZATION PANEL.....2 [by CM2]*.....CHECKED*

Field elevation of departure aerodrome..... Set

This is to ensure correct elevation set for a possible relandinq after take-off

AUTO / MAN button.....Check in / dark

CAB ALT selector .....Check full left / DN position

CAB DUMP Buttons.....Check latched dark

NOTE: Two micro switches in the power lever quadrant give a signal to the solenoid of the pneumatic outflow valve to open and depressurize the cabin, prepressurization will take place on ground (electro-pneumatic and pneumatic outflow valve are closed) when all doors are properly closed and either power lever is advanced out of ground idle position. Two door safety circuits ensure that the outflow valves do not open if a false door open signal is received from a door proximity switch when the aircraft is airborne."

Chapter 2.5.2.9, *"EXPANDED – FL 100 CHECKLIST"*, stipulates the following with regard to monitoring cabin pressure under item 2:

"PRESSURIZATION .....PM.....CHECK

Monitor the Cabin Pressurization Panel and make sure: Cabin Altitude Rate of Climb is climbing at the correct rate. Cabin Altimeter indicates correct cabin altitude for ambient altitude. Cabin Differential pressure is increasing."

Chapter 2.5.2.10, *"EXPANDED – CRUISE CHECKLIST"*, stipulates the following with regard to cabin pressure under item 3:

"DIFF. PRESSURE & CABIN alt..... PM ..... NORMAL

Monitor the Cabin Pressurization Panel and make sure:

Cabin Altitude Rate of Climb has stabilized at zero.

Cabin Altimeter indicates correct cabin altitude for ambient altitude."

Chapter 2.5.2.11, *"EXPANDED – DESCENT CHECKLIST"*, stipulates the following with regard to cabin pressure under item 1:

"PRESSURIZATION ..... PM..... (DEST.) DESCENDING

Elevation of landing runway .....Set / check"

1.17.1.3 Findings in the simulator

In the simulator, the operator determined that many of the tested pilots did not notice if the full left / DN position of MAN CAB ALT control knob was set incorrectly during cockpit preparation.

1.17.2 Maintenance company

1.17.2.1 General

Maintenance work on the operator's HB-AES aircraft was conducted by RUAG Aviation. RUAG is a support provider for aircraft and the integration of systems and components for civil and military aviation. Its core competencies include repair and maintenance work.

RUAG Aviation is based in Emmen, near Lucerne (Switzerland). The company has a presence in various locations in Switzerland, including Bern-Belp Airport, as well as in Germany and the USA; it employs approximately 2300 employees.

1.17.2.2 Heavy maintenance work

The maintenance company conducted the heavy maintenance visit (HMV) and control work in accordance with the regulations and worksheets of the aircraft manufacturer.

After completion of the HMV work, tests including a fuselage - special test (leak test) were performed. This test involves placing the cabin under maximum differential pressure and determining whether the over-pressure valve is functioning. Following this there is testing in stages to determine the time required for the differential pressure to fall from 6.5 PSI to 5 PSI, 6.5 PSI to 3.5 PSI and 6.5 PSI to 2.0 PSI. In doing so, it was not allowed to go below the time of 100, 220 and 365 seconds respectively. If these time limits are not met, there is a leak. The post-HMV test was successful, i.e. there were no leaks.

1.17.3 Procedure for emergency descent

Chapter 3 of the OM B, Abnormal and Emergency Procedures, stipulates the following in relation to emergency descents:

3.2.8.3 Emergency Descent

An Emergency Descent, if required, is normally carried out at VMO. If the structural integrity of
the aeroplane is in doubt, however, limit the descent airspeed as much as possible and avoid
high maneuvering loads. Moving the condition levers to MAX increases drag in order that the
descent to lower altitude may be done in a timely fashion.

PF	PNF
"EMERGENCY DESCENT" **"MEMORY ITEMS"**	**"EMERGENCY DESCENT"**
POWER levers (both) ..... FI Descent ..... Initiate (M_{MO}/V_{MO}) Mayday call..... Perform	SEAT BELT/NO SMOKING sign .....ON CONDITION levers (both) ..... MAX Cabin call ..... Perform Altitude preselect .....10'000 or ..... MEA/MORA Transponder 7700
"MEMORY ITEMS COMPLETED" **"EMERGENCY CHECK – RAPID DECOMPRESSION"**	**"MEMORY ITEMS COMPLETED"**
Continue according QRH	

Figure 4: Copy from the operator's OM B

The following emergency descent procedure is published in the quick reference handbook (QRH) checklist referred to in the OM B:

RAPID DEPRESSURIZATION/ EMERGENCY DESCENT

- Oxygen Masks On/100%
- Mic switch ..... Mask
- Passenger Signs ..... On

EMERGENCY DESCENT, accomplish as req'd:

- Power levers ..... Flight Idle
- Condition Levers ..... Max
- Airspeed ..... Vmo

***Note**: If structural integrity is in doubt, limit airspeed as much as possible and avoid high maneuvering loads.*

Figure 5: Copy from the aircraft manufacturer's QRH

1.18 Additional information

After flight SRK 600 landed, the maintenance company that had conducted the HMV carried out a re-inspection of the cabin pressure control system. A visual inspection of the forward outflow valve indicated that there was a small piece of insulation material located between the valve cover and air tube (cf. Annex 4). However, a practical experiment indicated that the valve could be tightly sealed despite this insulating material.

The operator then conducted a test flight in agreement with the Investigation. The pilot employed for this purpose stated the following [translated from German]: *"In our test flight after the incident we compared the cabin altitude and differential pressure based on the QRH abnormal checklist CPCS AUTO FAIL. The system worked flawlessly and no deviation from the nominal value could be found."*

On behalf of the SAIB-AD, the same pilot again noted during a normal flight in December 2012 the cabin altitude as a function of the flight altitude when climbing. The recordings approximately correspond to the data required by the manufacturer in its checklist for manual operation of the cabin pressure control system (cf. chapter 1.6.3).

1.19 Useful or effective investigation techniques

Not applicable.

2 Analysis

2.1 Technical aspects

2.1.1 General

There are no indications of any pre-existing technical defects which might have caused or influenced the serious incident. It could particularly excluded that temporarily dysfunctions or cabin leakage, e.g. door seals, had an impact.

2.1.2 Cabin pressure system

As described in chapter 1.6.3, before take-off there is a pre-pressurization phase, during which a differential pressure is established, i.e. the cabin altitude is reduced to a level 300 ft lower than that of the take-off aerodrome. Only at an altitude of 10 000 ft (FL 100) does the cabin altitude begin to rise. The commander stated that while working through the FL 100 checklist, the cabin altitude was usually approximately 1600 ft.

This statement was based on the experience of the commander, as the operator's Bern-Belp homebase, from which approximately 50% of flights took off, has a reference altitude of 1673 ft. If after taking off from Bern-Belp the cabin altitude is read while working through the FL 100 checklist, this value must correspond approximately to the aerodrome elevation, since according to the differential pressure build-up, the cabin altitude begins to rise, and did begin to rise and in this case did so at exactly this point. The statement of the copilot that the cabin rate was practically zero at this checklist point corresponds to experience for the same reason.

After taking off at 14:57:02 UTC, 16 minutes and 20 seconds passed until the aural warning sounded at 15:13:22 UTC and the CAB ALT caution message was displayed which is triggered at a cabin altitude of 9500 ft. If it is assumed that the forward outflow valve was not fully closed, the cabin altitude would have increased continuously after take-off at an average rate of approximately 480 ft/min. This climb rate approximately corresponded to the normal rise in cabin altitude, whereby the digital computer ensures that the rate of 550 ft/min is not exceeded (cf. chapter 1.6.3.2).

After reaching FL 270, and also during the descent, the cabin altitude continued to increase until the altitude of the aircraft was the same as the cabin altitude. Assuming that the cabin rate was maintained, this point would have been achieved when the aircraft descended and passed approximately 11 700 ft. The cabin altitude then fell and remained at the aircraft altitude of 11 000 ft, when the pressure regulation was switched to manual mode in accordance with the checklist. This also explains why the oxygen masks were not deployed in the cabin. For this, the cabin altitude would have had to increase to 13 500 ft.

The continuous rise in the cabin altitude leads to the conclusion that the forward outflow valve was not entirely closed at the time of take-off. This does not correspond to the copilot's statement that he had checked that the MAN CAB ALT control knob had been in the DN position when he went through the checklist during cockpit preparation for the flight (cf. chapter 1.17.1.2). A complicating factor in this context is that the MAN CAB ALT control knob is active regardless of the selected mode (automatic or manual) and therefore the forward outflow valve does not automatically close when switched to auto mode.

Since the cabin pressure altitude could be managed in MAN mode (cf. point 6 in the respective checklist in Annex 5), as the copilot stated, it can be concluded

that the forward outflow valve worked properly but was not fully closed at the very beginning.

Adversely in this context is the fact that the position of the forward outflow valve is nowhere displayed. The crew can therefore only indirectly determine whether the forward outflow valve is closed via the position of the MAN CAB ALT control knob. Only the cabin altitude, cabin pressure differential and cabin rate are indicated on the corresponding system page (cf. figure 2, chapter 1.6.3). If, as in the serious incident which is the subject of the investigation, the rate of climb is normal, it is only possible to recognise that the forward outflow valve is open if, as the checklist demands, the following two values are checked beside the cabin rate of climb: *"Cabin Altimeter indicates correct cabin altitude for ambient altitude. Cabin Differential pressure is increasing."* It should be noted that this review is practically impossible for the crew, because it occurs in a flight phase in which these values are constantly changing and there is a lack of specific information for comparison.

2.1.3 Communications

The flight attendant stated that she could not understand the commander via the interphone, while the commander donned her oxygen mask. The commander also stated that she had not understood the flight attendant on the interphone. Even though, as a result of the flight attendant's aviation experience, she informed passengers comprehensively and in a manner appropriate to the situation, it must be noted that this represented a safety deficit. In an emergency situation, clear and unrestricted communication via the interphone is of great importance. It is an indispensable prerequisite for appropriate action by all those involved.

2.2 Human and operational aspects

2.2.1 Crew

For the flight preparation, the copilot worked according to the FLIGHT DECK PREPARATION CHECKLIST. In the case of the checkpoint regarding the setting of the MAN CAB ALT control knob, he had to examine factors including whether this was in the full left / DN position (cf. chapter 1.17.1.2) in order to ensure that the forward outflow valve was closed. The copilot stated that he had examined it. The investigation came to the conclusion that this valve was not fully closed. This means that the MAN CAB ALT control knob was not in the full left / DN position. However, the position of the forward outflow valve is not recorded on the flight data recorder.

It seems plausible for the following reason that the control knob, not being in the full left / DN position, was not noticed during cockpit preparation: In normal operation, this control knob is not used before, during, or after the flight. It is a commonly observed psychological phenomenon that the position of such a control element is often overlooked when working through a checklist, as it is unconsciously assumed that it is in the correct position. Tests in the operator’s simulator also indicated that during cockpit preparation, many of the tested pilots did not notice that the MAN CAB ALT control knob had not been set to the full left / DN position and was therefore incorrect.

Controls that are used only in rare cases can be fixed in a certain position: switches can be secured with a safety wire, while push buttons can be secured using a cover. This means that they no longer need to be checked in the checklists for normal operation.

After take-off, while climbing and passing FL 100, the copilot worked through the FL 100 checklist. He had to check the following points (cf. chapter 1.17.1.2): *"Cabin Altitude Rate of Climb is climbing at the correct rate. Cabin Altimeter indicates correct cabin altitude for ambient altitude. Cabin Differential pressure is increasing."* The review of the relevant parameters was performed on the corresponding system page (cf. figure 2, chapter 1.6.3). Both pilots noticed that the parameters displayed did not correspond to the usual situation. The commander noticed that the cabin altitude was approximately 3000 ft. According to her experience it is usually 1600 ft. However, the cabin rate of climb corresponded to the usual value. The copilot noticed that the rate of climb was slightly higher than usual in his experience. This information is consistent with the reconstructed cabin altitude gradient. However, these unpronounced deviations from the values the pilots were used to experiencing did not provoke any reaction.

In particular, the effective cabin altitude would have indicated that this matter should be further investigated. Since the crew did not consult the CPCS / OXYGEN system page anymore during the course of the continued climb, they were also unable to notice that the cabin altitude continued to rise.

The crew only became aware of the cabin altitude again when the CAB ALT caution message was triggered with an additional aural warning tone (triple chime). At the same time the commander noticed the cabin altitude on the CPCS / OXYGEN system page. The crew reacted to this warning quickly, purposefully and safety-consciously with an immediate and decisive emergency descent. This also made it possible to prevent the deployment of oxygen masks in the passenger cabin.

Communication with air traffic control was appropriate to the situation and helped to keep the situation under control.

The commander further stated that she was unable to communicate with the flight attendant via the interphone. However, as the commander was able to hear what the flight attendant said to the passengers on the passenger information system, and that she was calm, the commander decided to attempt to make contact with the flight attendant at a later point. These considerations were appropriate to the situation.

The decision of the crew to reduce speed for safety reasons due to possible structural damage was safety-conscious. The crew also decided to turn back from a position approximately 20 km south of Zurich and return to Bern rather than land at Zurich Airport. This decision was based on the fact that Bern-Belp was the homebase of the aircraft and therefore represented the best solution in terms of operations.

2.2.2 Flight attendant

As the flight attendant was unable to communicate with the pilots via the interphone, she informed the passengers on the basis of her own situational assessment. She realised that the pilots had donned their oxygen masks. Since no oxygen masks were deployed in the cabin and she did not find the emergency descent very steep, she did not consider decompression. These considerations are evidence of a systematic and logical method of working. From her previous work as a flight attendant on a scheduled airline and appropriate experience she considered smoke in the cockpit and informed the passengers in relation to an impending emergency landing. This behaviour was prudent and safety-conscious.

2.2.3 Air traffic control

When at 15:14:55 UTC the crew declared an emergency with *"Mayday"* and requested a descent, air traffic control immediately issued the appropriate clearance. Air traffic control then supported the crew with flight level information and heading instructions. They also gave the crew additional guidance for them to make a situational assessment by providing appropriate distance information and the offer of landing in Zurich. In summary it can be stated that the actions of the air traffic control officers involved in the serious incident were forward-thinking and safety-conscious.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for VFR/IFR transport.
- Both the mass and centre of gravity of the aircraft were within the permitted limits according to the AFM at the time of the serious incident.
- The investigation produced no indications of any pre-existing technical faults which might have caused or influenced the serious incident.
- Between 30 January 2012 and 13 March 2012 the aircraft was on a heavy maintenance visit (HMV). At this time the aircraft indicated 16 091:06 aircraft hours and 14 837 aircraft cycles.
- On 13 March 2012, after the completion of the HMV, there was a 1:38-hour test flight, during which no complaints were logged with regard to the cabin pressure control system.

3.1.2 Crews

- The pilots were in possession of the necessary licences for the flight.
- There are no indications of the pilots suffering health problems during the flight involved in the serious incident.

3.1.3 History of the flight

- After taking off from Bern-Belp the aircraft climbed and passed flight level (FL) 100 at 15:01:28 UTC.
- At approximately this time, the crew was working through the points of the 'FL 100 checklist'. The commander noticed a cabin altitude of approximately 3000 ft with a normal cabin climb rate.
- At 15:13:22 UTC, shortly after reaching the cruising altitude of FL 270, the CAB ALT caution message was displayed in the cockpit and at the same time an audible warning tone (triple chime) alerted the crew to this annunciation.
- The commander noticed the cabin altitude was approximately 9500 ft and further rising.
- Both pilots immediately donned their oxygen masks and the commander initiated a rapid emergency descent.
- At 15:14:55 UTC the crew reported: *"Skyfox six hundred, Mayday, Mayday, Mayday, we request to descend"*.
- The ATCO immediately gave unrestricted clearance to descend. At this point the aircraft was located approximately 20 km south of Zurich Airport.
- During the emergency descent, the commander and the flight attendant noticed that they could not understand each other via the interphone.
- The flight attendant informed the passengers on the basis of her own situational assessment.
- Air traffic control assisted the crew with flight level information and heading instructions.

- The crew regulated the cabin pressure control system in manual mode.
- The crew decided to return to Bern-Belp at reduced speed.
- Air traffic control provided the crew with orientation for the remaining distances to Zurich and Bern-Belp respectively and offered a landing at Zurich.
- The crew adhered to their decision to return to Bern-Belp.
- During the flight back to Bern-Belp the flight attendant had access to the cockpit and was then able to receive orientation from the crew.
- The remainder of the flight was uneventful and the aircraft landed on runway 14 at Bern-Belp at 15:44 UTC.

3.1.4 General conditions

- The position of the forward outflow valve (whether it is closed, open or partially open) is not explicitly displayed to the crew.
- The pilots and the flight attendant did not understand each other via the interphone.
- The weather conditions had no influence on the serious incident.

3.2 Causes

The serious incident is attributable to the fact that when the commercial aircraft took off, the forward outflow valve was not completely closed and the cabin altitude became excessive.

The failure of the crew not to notice an incorrectly set operation element for controlling the cabin pressure control system was identified as a direct cause of this serious incident.

The following factors contributed to the occurrence of the serious incident:

- The control of the forward outflow valve, which is provided for in manual mode, also functions in automatic mode.
- The position of the forward outflow valve is not displayed to the crew.

Although the following factor did not directly cause the serious incident, in the context of the investigation it was identified as a risk factor:

- The commander and flight attendant could not understand each other via the interphone.

4 Safety recommendations and measures taken since the serious incident

According to the provisions of Annex 13 of the International Civil Aviation Organization (ICAO), all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which has to decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, any establishment and any individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

Swiss legislation provides for the following regulation regarding implementation in the Ordinance on the Investigation of Aircraft Accidents and Serious Incidents:

"Art. 32 Safety recommendations

[1] DETEC, on the basis of the safety recommendations in the SAIB reports and in the foreign reports, shall address implementation orders or recommendations to the FOCA.

[2] The FOCA shall inform DETEC periodically about the implementation of the orders or recommendations pronounced.

[3] DETEC shall inform the SAIB at least twice a year on the state of implementation by the FOCA."

4.1 Safety recommendations

4.1.1 Safety recommendation for controlling the forward outflow valve of the DO338-100

4.1.1.1 Safety deficit

On 14 March 2012 at 14:56 UTC the DO328-100 aircraft took off from Bern-Belp (LSZB) on a scheduled flight according to instrument flight rules to Vienna-Schwechat (LOWW). On board were three crew members and 17 passengers.

Approximately one minute after reaching cruising altitude (FL 270), the CAB ALT caution message was displayed and at the same time an audible warning tone (triple chime) alerted the crew to this annunciation. At that moment the cabin altitude was 9500 ft and still rising. The crew donned their oxygen masks and immediately initiated an emergency descent. They issued a mayday message and immediately received unlimited clearance to descend from the air traffic control officer.

At this time the aircraft was 20 km south of Zurich. The crew decided to return to Bern-Belp at reduced speed. In accordance with the appropriate checklist the cabin pressure control system was then controlled manually until landing. The investigation led to the conclusion that the forward outflow valve had not been fully closed when the aircraft took off.

This situation arose because the crew failed to notice that the control knob for controlling the forward outflow valve was set in the incorrect position.

The following factors contributed to the occurrence of the serious incident:

- The control of the forward outflow valve, which is provided for in manual mode, also functions in automatic mode.
- The position of the forward outflow valve is not displayed to the crew.

4.1.1.2 Safety recommendation no. 492

"Die Europäische Agentur für Flugsicherheit (European Aviation Safety Agency – EASA) sollte zusammen mit dem Flugzeughersteller Massnahmen ergreifen, damit der Besatzung ein nicht geschlossenes forward outflow valve insbesondere im automatischen Betriebsmode besser erkennen kann."

[The European Aviation Safety Agency (EASA) should, together with the aircraft manufacturer, take measures to ensure that an improperly closed forward outflow valve is better recognizable for the crew, particularly in automatic mode.]

4.2 Measures taken since the serious incident

None.

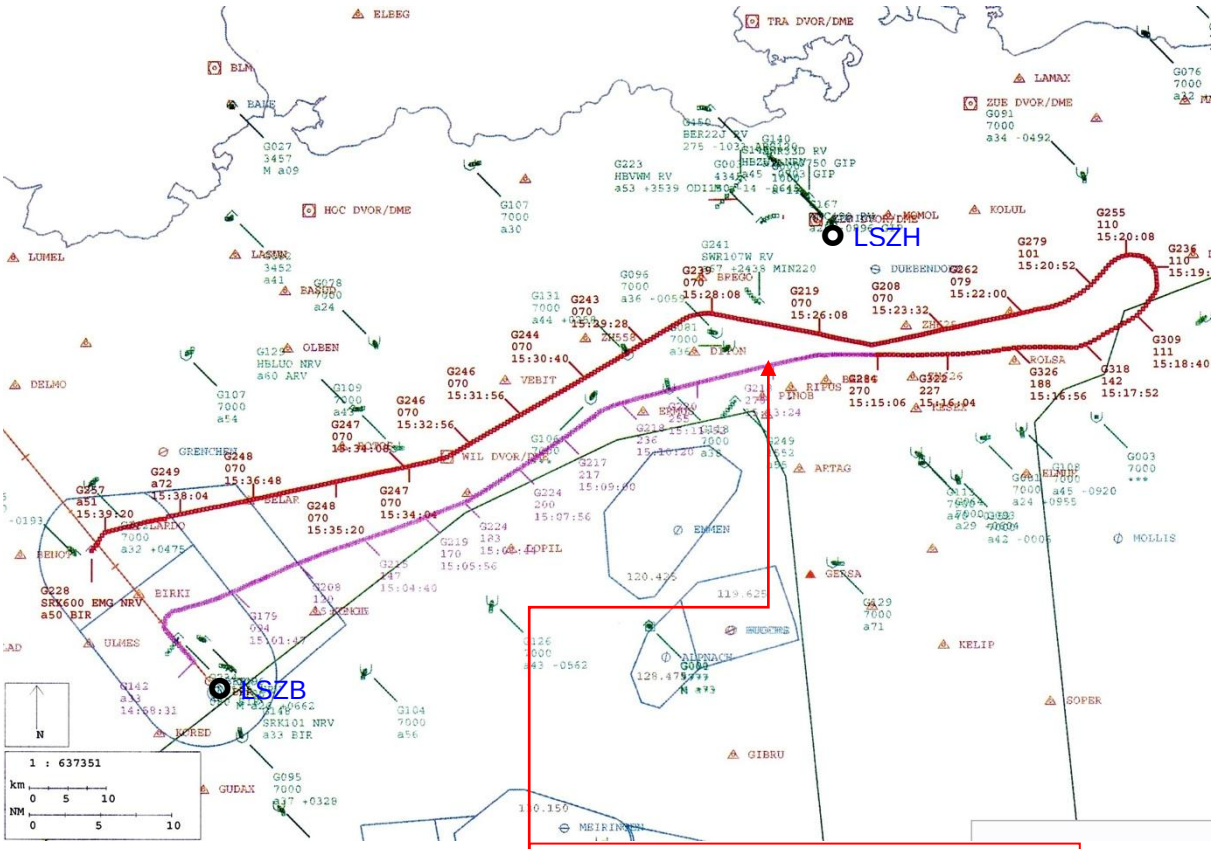
Payerne, 28 November 2014 Swiss Accident Investigation Board

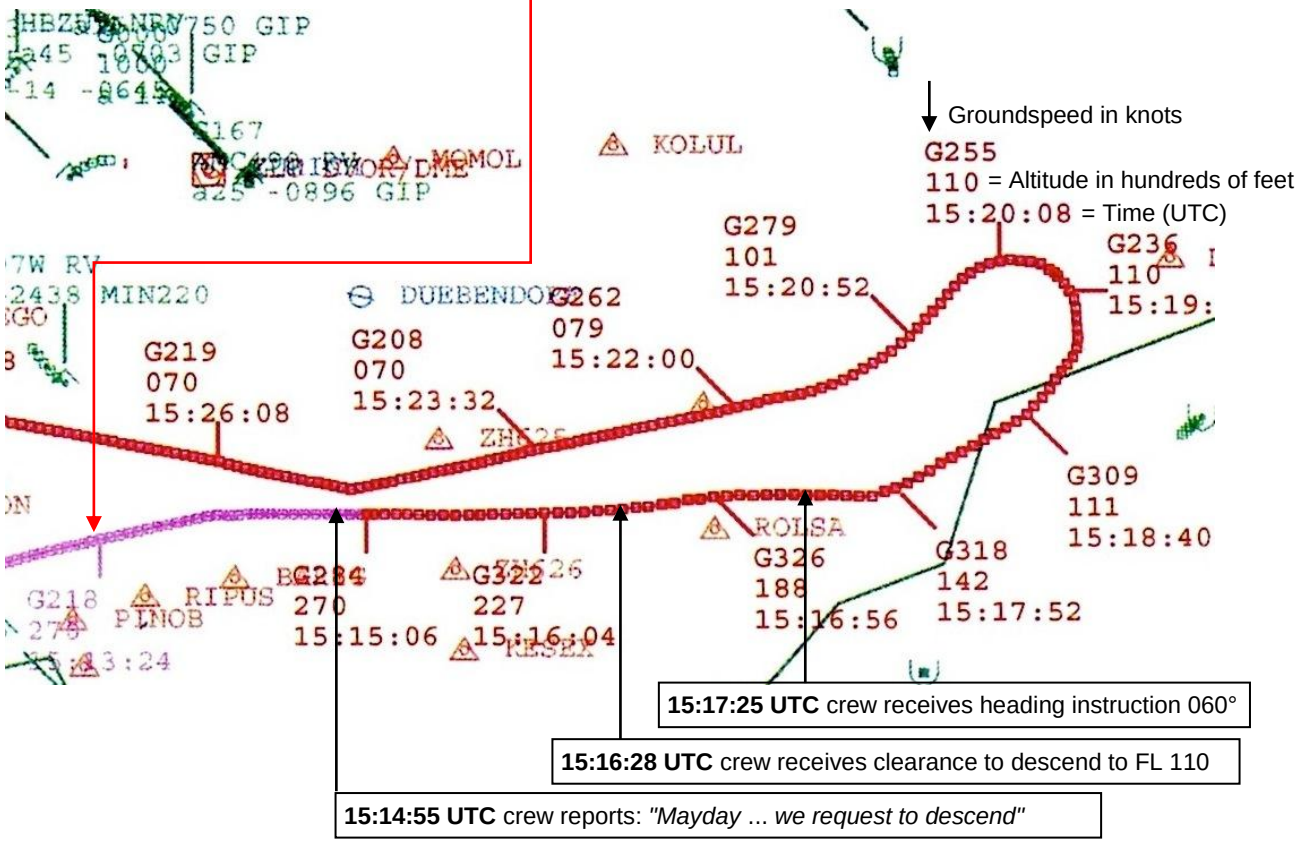
This final report was approved by the management of the Swiss Accident Investigation Board SAIB (Art. 3 para. 4g of the Ordinance on the Organisation of the Swiss Accident Investigation Board of 23 March 2011).

Berne, 9 december 2014

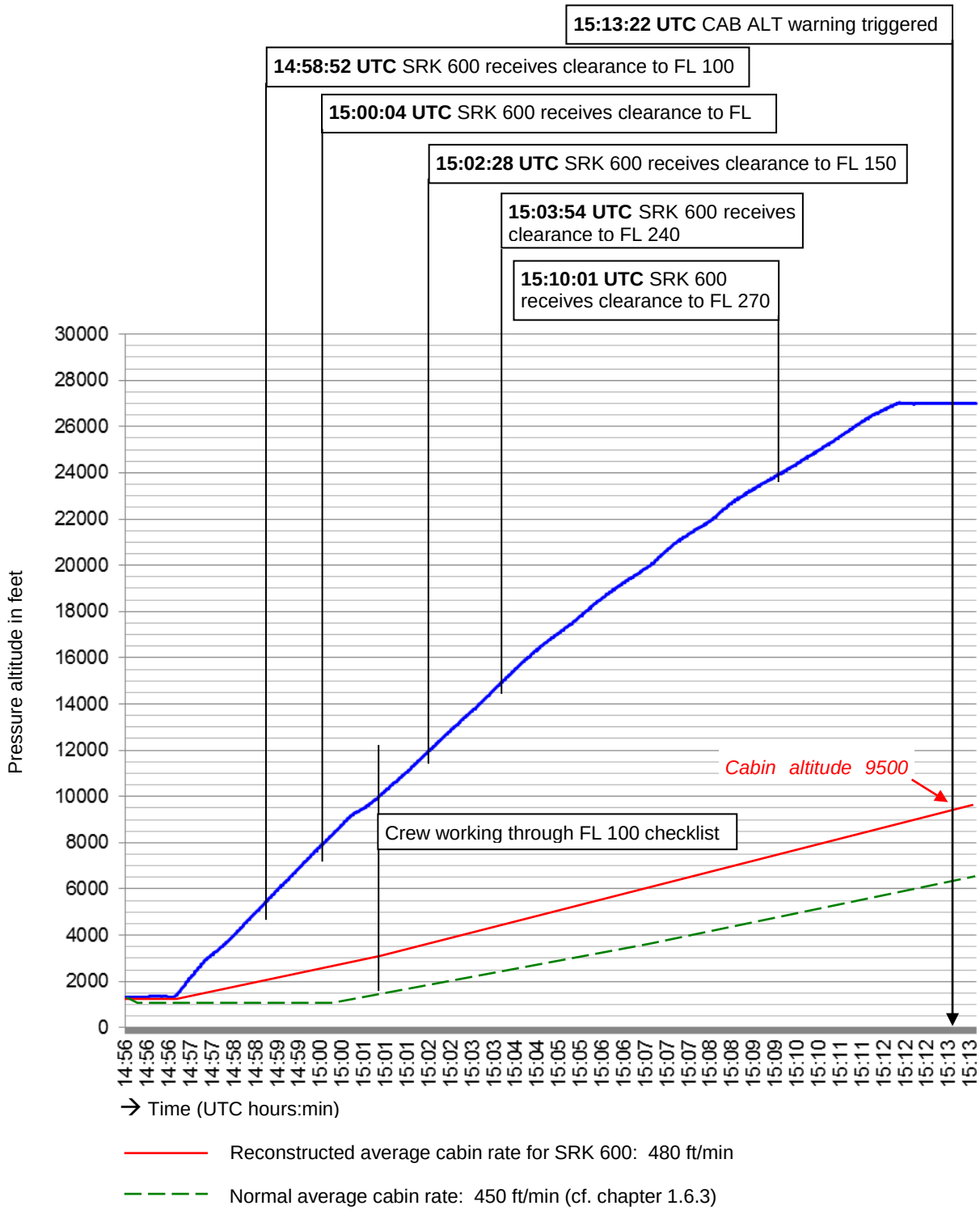
Annexes

Annex 1: Radar recording of the flight path

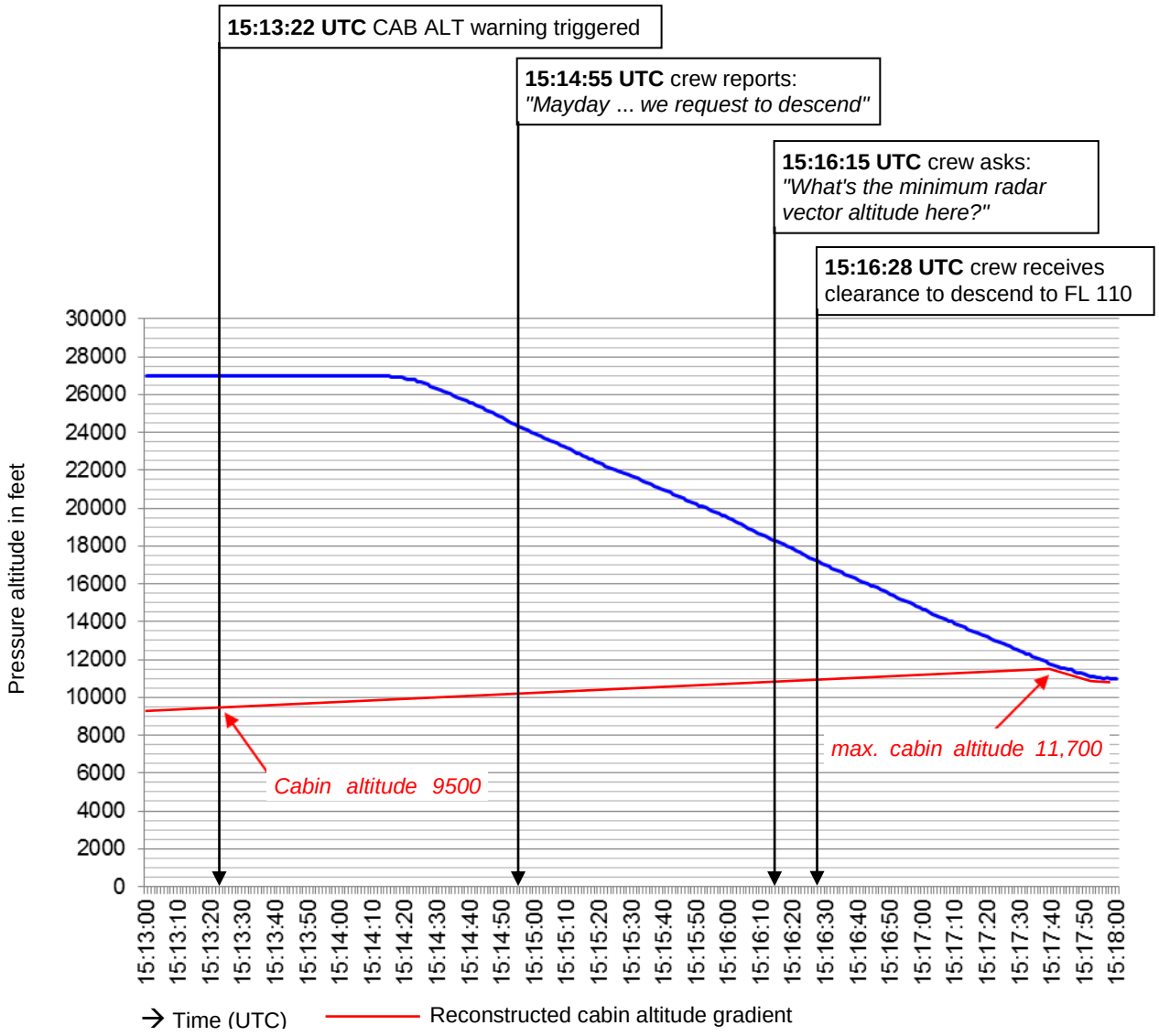


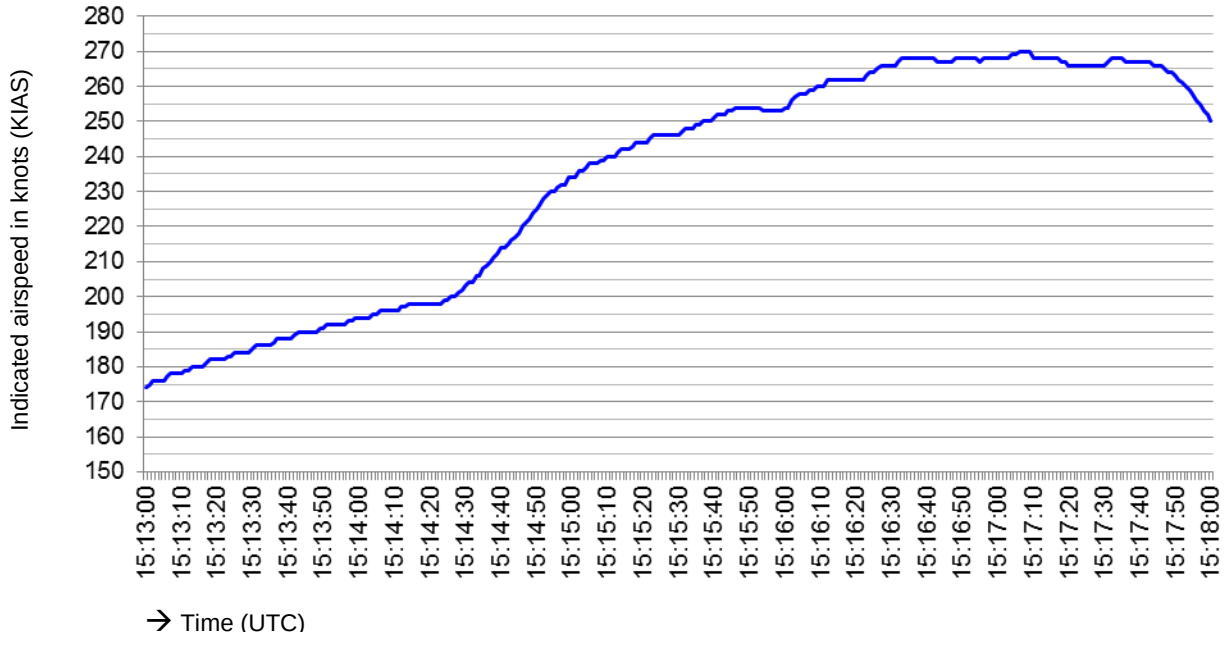


Annex 2: Flight path profile during the climb



Annex 3: Flight path profile at the time of the serious incident





Annex 4: Insulating material on forward outflow valve

Annex 5: Checklist for excessive cabin altitude

CAB ALT

EXCESSIVE CABIN ALTITUDE

ACTION

1.	**Crew oxygen masks**	**DON – 100%**
2.	**Oxygen mask mike**	**Activate–adjust speaker VOL – or use headset with oxygen mask to establish crew communication**
3.	SEAT BELT / NO SMOKING switches	ON
4.	CABIN ALTITUDE and RATE	Check
5.	PRESSURIZATION CONTROL MODE	MAN
6.	MAN CAB ALT selector	DN
7.	Descent	Initiate to 10 000 ft or minimum enroute altitude whichever is higher

If CABIN ALTITUDE can be controlled or CAB ALT Caution extinguishes:

8.	PRESSURIZATION CONTROL MODE	Leave in MAN
9.	CPCS AUTO FAIL procedure	Apply

If CABIN ALTITUDE cannot be controlled:

10.	OXYGEN DROP–OUT switch	Unlatch – MAN

If DROP–OUT unsuccessful:

11.	OXYGEN separation valve	Select connected mode

If flight is continued above 10 000 ft:

12.	Crew oxygen masks	NORM
13.	Oxygen duration	Check – refer to the OXYGEN CONSUMPTION tables 1 and 2 below. – Add the oxygen consumption required for descent (table 1) to the oxygen consumption required for 2 pilots at the altitude to be flown (table 2). When this oxygen quantity is reached proceed with step 14.
14.	OXYGEN PAX–SUPPLY button	OFF
15.	OXYGEN separation valve	Closed
16.	Advise cabin attendant that only FIRST AID OXYGEN is available.	

cont'd next page

Copy from the operator's OM B (*chapter* 3, *Abnormal and Emergency Procedures*; the procedure is identically to the published procedure in the aircraft manufacturer's AOM *Volume* 1, *Emergency Procedures* 03-02-00).

Annex 6: Publication of a deviating statement

According to ICAO Annex 13 chapter 6.3 in connection with DOC 9756 chapter 1.4 the SAIB publishes the following statement of the accredited representative of Germany. This statement deviates from the SAIB's opinion, which is published in the final report. The German BFU requested their publication. The statement will not be commented by the SAIB.

„Im Kapitel 2.1.2 wird die Hypothese aufgestellt, dass das Ansteigen der Kabinenhöhe auf ein nicht vollständig geschlossenes Forward Outflow Valve zurückzuführen ist. Diese Hypothese wird durch verschiedene Fakten untermauert und erscheint auch aus Sicht der BFU als sehr wahrscheinlich, obwohl sie im Widerspruch zur Aussage des Copiloten steht. Es ist folglich auch sehr wahrscheinlich, dass die Cockpitvorbereitung nicht korrekt durchgeführt wurde.

Die CAB ALT – EXCESSIVE CABIN ALTITUDE-Checkliste des AFM der DO 328-100, welche sich auch in dem OM B des Luftfahrtunternehmens wiederfindet, enthält vor dem Einleiten eines Emergency Descents die Punkte PRESSURIZATION CONTROL MODE ... MAN und MAN CAB ALT selector ... DN. Folgt man der Hypothese, dass der Druckverlust auf eine falsche Stellung des Manual Cabin Altitude Selectors zurückzuführen ist, wäre bei der Befolgung der Vorgaben des AFM und des OM/B sofort die Kabinenhöhe wieder kontrollierbar gewesen und ein Emergency Descent hätte nicht durchgeführt werden müssen.

Folglich hat das zweimalige fehlerhafte Umsetzen der bestehenden Verfahren sehr wahrscheinlich ursächlich zu dem Ereignis beigetragen. Die Gründe für die fehlerhafte Umsetzung bleiben hierbei offen.

Die im Bericht enthaltene Sicherheitsempfehlung an die EASA bezüglich einer Designänderung des Flugzeuges halte ich vor diesem Hintergrund weder zielführend noch dem durch das Ereignis erkennbar gewordenen Sicherheitsrisiko angemessen."