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Swiss Accident Investigation Board SAIB

Aviation Division

Final Report No. 2199 by the Swiss Accident Investigation Board SAIB

concerning the serious incident involving the AVRO 146-RJ100 aircraft, registration HB-IXW

on 2 July 2012

24 NM south-east of omni-directional radio beacon Rolampont (RLP), France

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Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass nach einem Defekt im rechten Druckluftverteilsystem das Kabinendruckbelüftungssystem auf FL 244 (7437 m) ganz ausfiel und die Besatzung gezwungen war, einen Notabstieg auf eine sichere Flughöhe durchzuführen.

Zum schweren Vorfall hat beigetragen, dass das *airconditioning pack 1* vor dem Flug stillgelegt worden war.

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 accident 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 times in this report, unless otherwise indicated, follow the coordinated universal time (UTC) format. At the time of the serious incident, Central European Summer Time (CEST) applied as local time (LT) in Switzerland. The relation between LT, CEST and UTC is:
LT = CEST = UTC + 2 hours

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Final Report

Synopsis

Owner	Swiss International Air Lines Ltd. Postfach, CH-4002 Basel
Operator	Swiss European Air Lines AG, Malzgasse 15, CH-4052 Basel
Manufacturer	British Aerospace Regional Aircraft Ltd.
Aircraft type	AVRO 146-RJ100
Country of registration	Switzerland
Registration	HB-IXW
Location	24 NM south-east of omni-directional radio beacon Rolampont (RLP), flight level (FL) 244, France
Date and time	2 July 2012, 10:09 UTC

Investigation

The serious incident occurred on 2 July 2012 at 10:09 UTC. The notification was received on the same day at 11:00 UTC at the SAIB, which opened an investigation at approximately 11:45 UTC, after the handling of this event had been delegated by the French investigating authority, the Bureau d' Enquêtes et d'Analyses (BEA).

The SAIB informed the following States about the serious incident by way of notification: France and the United Kingdom. Both countries nominated an authorised representative and offered the SAIB their support.

This final report is published by the SAIB.

Summary

On 2 July 2012 at 09:47 UTC the AVRO 146-RJ100 aircraft, registration HB-IXW under flight number LX 456 and radio call sign "*Swiss four seven three foxtrot*" took off on a scheduled passenger flight from Zurich (LSZH) to London City (EGLC).

After a flight time of approximately 22 minutes and when in climb at flight level (FL) 244, various warning lights illuminated, including the R ZONE HI TEMP warning. This warning triggered several automatic shutdowns, including the shutdown of airconditioning pack 2. At this time, the aircraft was 24 NM south-east of the Rolampont omni-directional radio beacon (RLP) in France.

Since airconditioning pack 1 was already deactivated at the commencement of the flight, the cockpit crew realised that cabin pressurisation was no longer ensured and that the pressure inside the aircraft would drop. The crew donned their oxygen masks. A good minute after the first alerts, the CABIN HI ALT warning light illuminated. The crew reported the emergency situation to the "Reims Control" air traffic control centre and initiated an emergency descent. Shortly afterwards the oxygen masks in the cabin were automatically deployed. These were donned by the passengers in accordance with the cabin crew's instructions.

At 10:15:40 UTC the aircraft reached FL 100. After a detailed analysis and assessment of the situation, the crew decided to return to Zurich. The approach and landing were uneventful. None of the passengers or crew was injured.

Causes

The serious incident is attributable to the fact that after a defect in the right bleed air system the cabin pressurisation system failed completely at FL 244 (7437 m) and the crew were forced to make an emergency descent to a safe altitude.

The fact that airconditioning pack 1 had been deactivated prior to the flight contributed to the serious incident.

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 communications, the flight data recorder, radar data and the statements of the crew members were used. The commander was pilot flying (PF) and the copilot was pilot not flying (PNF) for the entire duration of the flight.

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

1.1.2 Pre-history

On 1 July 2012, on flight LX 1171 from Stuttgart (EDDS) to Zurich (LSZH), the following defect was entered in the logbook: "*After engine start with bleed air on (APU[1] u/s) smell of burned oil in flight deck, disappeared in climb out"*. Aircraft maintenance carried out a check using a so-called oil tracer with the engines running. Since the analysis of the oil tracer data takes some time, an additional boroscope check was performed. This identified oil traces on engine 1, in the area of bearing #9. In order to be able to release the aircraft without delay on the next day for flight LX 456, airconditioning pack 1 was deactivated. The bleed air supply from engine 1 was not disabled. The APU had been out of service since 26 June 2012.

1.1.3 History of the flight

On 2 July 2012 at 09:47 UTC the AVRO 146-RJ100 aircraft, registration HB-IXW under flight number LX 456 and radio call sign “Swiss four seven three foxtrot” took off on a scheduled passenger flight from Zurich (LSZH) to London City (EGLC).

The take-off and climb were uneventful. At 09:59:30 UTC, with clearance to FL 240, the crew were instructed by Swiss Radar to change to Reims Control at the 134.405 MHz frequency. Flight LX 456 then promptly received clearance to climb to FL 300. At 10:08:22 UTC at FL 244, climbing to the cleared flight level 300, several warning lights illuminated, including the R ZONE HI TEMP warning (cf. Annex 3). This warning triggered several automatic shutdowns, including the shutdown of airconditioning pack 2 (cf. Chapter 1.6.2.4). At this time, the aircraft was 24 NM south-east of the Rolampont (RLP) omni-directional radio beacon, in cloud. Since according to the crew's statement there was a risk of icing, the wing, tail, and engine anti-ice systems were activated. At 10:09:09 UTC the crew received an instruction from Reims Control to change to the 134.960 MHz frequency; this was acknowledged by the crew.

Since airconditioning pack 1 was already deactivated at the commencement of the flight, the cockpit crew realised that cabin pressurisation was no longer ensured. They then requested clearance to descend at 10:09:40 UTC: *"... foxtrot, requesting descent, we have a pressurisation problem".* This call resulted in a query from the air traffic control officer: "*Station calling, say again*". The crew complied, but only repeated the call sign incompletely. Immediately afterwards, the frequency was occupied by two radio conversations with other aircraft. Meanwhile, the cockpit crew donned their oxygen masks.

At 10:09:45 UTC, the CABIN HI ALT warning and the red attention getting lights illuminated and a triple chime sounded.

[1] APU – auxiliary power unit.

At 10:10:31 UTC, at FL 256, the crew reported an emergency as follows: *'mayday, mayday... emergency descent to flight level one hundred."* As a result of limited intelligibility with oxygen masks donned, this radio call again resulted in a query from the air traffic control officer.

The emergency descent was initiated at 10:11:05 UTC without a change of heading. A little later the crew changed the transponder code to 7700[2].

At 10:11:54 UTC, Reims Control gave the following clearance: *"Swiss four seven three foxtrot we have big difficulties to understand you, so you may descend to flight level one hundred, if you have to."*

During the descent at an average rate of descent of 3600 ft/min and an average indicated airspeed of 264 kt, the oxygen masks were automatically deployed in the cabin at approximately 10:11:40. Since the corresponding information via the PA system (pre-recorded announcement) was not activated, the chief flight attendant made this announcement in English and German. In seating row 1DEF, and at one aft flight attendant station, the oxygen masks were not deployed automatically. The oxygen masks in the first seat row were deployed manually by the chief flight attendant. The flight attendant at the aft flight attendant station used the oxygen mask in the toilet. Within a short time all passengers had donned their oxygen masks. As a result of a chemical reaction, the oxygen generators heated up and a visible bluish mist was produced. For a few passengers this caused some insecurity and slight eye irritation. According to statements from the cabin crew there was no panic.

At 10:14:46 UTC the air traffic control officer instructed flight LX 456 to change to the Paris Control frequency.

At 10:15:40 UTC the aircraft reached the preselected flight level 100. The commander reported to the cabin crew that the aircraft was now at a safe altitude and that the oxygen masks were no longer needed.

After a detailed analysis the crew decided to return to Zurich and reported this to Paris Control. At 10:18:25 UTC they received clearance to turn left and to adopt a heading for omni-directional beacon BLM.

At 10:20:10 UTC the crew reported as follows: *"normal operation, without air conditioning, pressurisation"*.

At 10:40:17 UTC flight LX 456 reported to Zurich Arrival. At this time, the aircraft was at FL 100 on a heading for the waypoint GIPOL, to the west of Zurich Airport. The air traffic control officer then guided the aircraft to runway 14 by means of heading vectors. At 10:55:04 UTC the Zurich Arrival air traffic control officer instructed flight LX 456 to change to the Zurich Tower frequency. The landing took place uneventful at 10:57:18 UTC.

The passengers were able to vacate the plane normally. One passenger was cared for by the airport medical staff.

1.1.4 Location of the serious incident

24 NM south-east of the omni-directional radio beacon Rolampont (RLP), FL 244.

[2] This code reports an emergency to the air traffic control centre.

1.2 Injuries to persons

1.2.1 Injured 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	4	93	97	Not applicable
Total	4	93	97	0

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 Commander

1.5.1.1 General

Person	Swiss citizen, born 1959
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 17 May 1995
Ratings	Type rating AVRORJ/BAe146 as pilot in command, valid till 27 January 2013 International radiotelephony for flights under visual and instrument flight rules RTI (VFR/IFR) Language proficiency: English level 4, valid till 27 April 2014 Night flying NIT(A)
Instrument flying rating	Instrument rating aircraft IR(A) Category III instrument approaches with AVRORJ/BAe146, valid till 27 January 2013
Last proficiency check	Licence proficiency check (LPC) on 13 December 2011
Medical fitness certificate	Class 1, restrictions: VDL (shall wear corrective lenses), valid from 28 December 2011 till 7 January 2013
Last medical examination	28 December 2011

1.5.1.2 Flying experience

Total	12 800 hours
on the type involved in the incident	4300 hours
during the last 90 days	35 hours
of which on the incident type	25 hours
as commander	9700 hours

1.5.1.3 Flight duty times

Start of duty in the 48 hours before the serious incident	30 June 2012 1 July 2012 2 July 2012	off duty off duty 08:30 UTC
End of duty in the 48 hours before the serious incident	30 June 2012 1 July 2012	off duty off duty
Flight duty times in the 48 hours before the serious incident	30 June 2012 1 July 2012	0 hours 0 hours
Rest times in the 48 hours before the serious incident	from 30 June to 1 July from 1 June to 2 July	off duty off duty
Flight duty time at the time of the serious incident	01:38 hours	

1.5.2 Copilot

1.5.2.1 General

Person	Swiss citizen, born 1966
Licence	Commercial pilot licence aeroplane (CPL(A)) according to Joint Aviation Requirements (JAR), first issued by the FOCA on 9 January 2001
Ratings	Type rating AVRORJ/BAe146 as copilot, valid till 24 January 2013 International radiotelephony for flights under visual and instrument flight rules RTI (VFR/IFR) Language proficiency: English level 4, valid till 24 January 2014 Night flying NIT(A)
Instrument flying rating	Instrument rating aircraft IR(A) Category III instrument approaches with AVRORJ/BAe146, valid till 24 January 2013
Last proficiency check	Licence proficiency check (LPC) on 22 January 2012
Medical fitness certificate	Class 1, no restrictions, valid from 15 February 2012 to 27 February 2013
Last medical examination	15 February 2012

1.5.2.2 Flying experience

Total	4130 hours
on the type involved in the incident	2869 hours
during the last 90 days	155 hours
of which on the incident type	155 hours

1.5.2.3 Flight duty times

Start of duty in the 48 hours before the serious incident	30 June 2012	off duty
	1 July 2012	off duty
	2 July 2012	08:30 UTC (standby from 03:00 UTC)
End of duty in the 48 hours before the serious incident	30 June 2012	off duty
	1 July 2012	off duty
Flight duty times in the 48 hours before the serious incident	30 June 2012	0 hours
	1 July 2012	0 hours
Rest times in the 48 hours before the serious incident	from 30 June to 1 July	off duty
	from 1 to 2 July	off duty (standby from 03:00 UTC)
Flight duty time at the time of the serious incident	01:38 hours	

1.6 Aircraft information

1.6.1 General

Registration	HB-IXW
Aircraft type	AVRO 146-RJ100
Characteristics	Four-jet commercial aircraft
Manufacturer	British Aerospace Regional Aircraft Ltd.
Year of manufacture	1995
Serial number	E3272
Owner	Swiss International Air Lines Ltd. Postfach, 4002 Basel, Switzerland
Operator	Swiss European Air Lines AG, Malzgasse 15, 4052 Basel, Switzerland
Engines	4 Allied Signal LF507-1F
Operating hours airframe	38 472 hours
Number of cycles	35 666
Max. permitted masses	Max. permitted take-off mass 44 999 kg Max. permitted landing mass 40 142 kg
Mass and centre of gravity	Both the mass and centre of gravity were within the permitted limits according to the aircraft flight manual (AFM).

Maintenance	The last scheduled maintenance work[3] (A07 - Check) took place on 18 June 2012 at 35 563 cycles.	
Technical limitations	In the deferred defect list (DDL), pack 1, APU, and flight guidance system (FGS) 2 were entered as INOP.	
Permitted fuel grade	JET A1 kerosene	
Registration certificate	Issued by the FOCA on 11 April 2007 (No. 6), valid till deletion from the aircraft register.	
Airworthiness certificate	Issued by the FOCA on 11 April 2007, valid till revocation by the appropriate authority of the state of registration.	
Certification	Cat. IIIA	RVR 200 m / DH 50 ft
Types of use	LVTO	RVR 125 m
	RVSM	
	RNAV	
	B-RNAV	RNP 5
	P-RNAV	RNP 1.0
	Continuing Airworthiness	
	EC2042/2003, Part M Subpart G	
	EFB	Class 2
	Dangerous goods	

1.6.2 Systems and indicators

1.6.2.1 General

The following sections mention and describe only those systems and indicators which had a relevant impact on the serious incident. The systems described in the following sub-sections relate to the time of the serious incident.

1.6.2.2 Bleed air system

The bleed air system provides the pneumatic pressure to drive the airconditioning packs. Hereinafter these are designated pack 1 and pack 2.

The bleed air distribution system is shown schematically in Annex 8.

Pack 1 relates to bleed air from the left air supply system. This is fed from engines 1 and/or 2 or from the auxiliary power unit (APU).

Pack 2 relates to the bleed air from the right air supply system. This is fed from engines 3 and/or 4 or from the auxiliary power unit (APU).

The bleed air gets to the respective pack via the pack valve. The pack valves regulate the air flow on the one hand and on the other serve as shut-off valves.

By means of switches (pack 1 and pack 2) on the air conditioning panel, the pack valves can be opened and closed (cf. Figure 1).

[3] In the case of the AVRO 146-RJ100 maintenance work is based on the number of cycles (take-off – landing).

The pack valves can be operated both electrically and pneumatically. If the electrical power fails or if the air pressure falls, the corresponding pack valve closes.

A flow switch is associated to each airconditioning pack (pack 1 and pack 2). On the airconditioning panel there are two annunciators **PACK 1 VALVE** and **PACK 2 VALVE** (cf. Figure 1).

The annunciators are illuminated if:

- a flow switch reports a low air pressure and the corresponding pack is switched ON

or

- with pack 1 or pack 2 switched to OFF, the associated PACK VALVE annunciator will illuminate when the airflow is maintained (i.e. the PACK VALVE fails to close) until the pressure in the pack decreases to a level where the flow switch contacts open.

In addition to the airconditioning system, the hot air from the engines is also used for de-icing purposes (cf. Chapter 1.6.2.5).

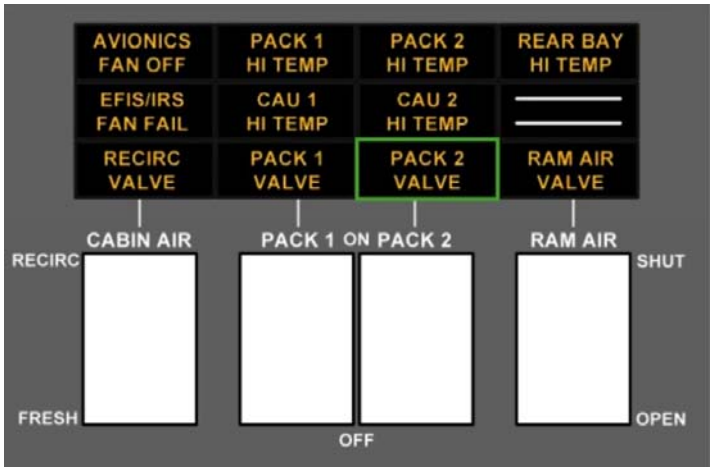


Figure 1: Air conditioning panel with PACK 1 and PACK 2 ON-OFF switches and PACK VALVE 1 and PACK VALVE 2 annunciators.

1.6.2.3 Air conditioning system

The air conditioning system performs the function of maintaining the air pressure and temperature in the aircraft at values which are comfortable for passengers and crew.

Compressed air flows from the engines via pack valves and airconditioning packs to the interior of the aircraft where it is fed via a distribution system to the cockpit and the passenger cabin. (cf. Annex 8).

The pack valves ensure a constant air supply. They also serve as shut-off valves, to shut off the air supply completely. The air temperature is regulated by the airconditioning packs.

The air pressure is regulated by the opening and closing of the two pressurization discharge valves, which are located on the left side of the fuselage.

The cabin pressurisation system consists of two air supply systems. The left air supply relates to compressed air from engines 1 and 2, and the right to air from engines 3 and 4. One of these supply systems is sufficient to maintain the air

pressure in the aircraft up to the maximum cruising altitude of 31,000 ft (9450 m) at a level corresponding to about 7000 ft (2134 m).

As mentioned above, the air pressure in the aircraft is regulated by pressurization discharge valves. The discharge valve is pneumatically operated and electrically controlled. A reference pressure is built up inside a reference chamber. This is modulated via a torque motor. If the pressure in the aircraft rises above the reference pressure, the discharge valve opens, air is discharged over board and the pressure drops. Conversely, if the pressure drops below the reference pressure, the discharge valve closes and the pressure rises.

The target for the reference pressure is provided by the pressurisation controller[4]. On it, the desired cabin altitude can be set by means of the cabin altitude selector (cf. Annex 9).

During flight LX 456 the pressurization controller was in automatic mode. In this mode the cabin altitude increases during the climb until it attains the set altitude at a rate of 525 ft/min, if the RATE rotary knob is at the detent. During a descent the rate is 375 ft / min.

In the present case the air supply to the cabin failed at 10:08:22 UTC. The air pressure in the cabin then fell and the pressurization discharge valves closed automatically. Owing to construction-related natural leaks from the airframe, the cabin altitude increased at about 2000 ft/min despite the closed pressurization discharge valves[5] . The passenger oxygen masks were deployed automatically when a cabin altitude of 13,250 ft was reached (cf. Chapter 1.6.2.6).

1.6.2.4 Temperature monitoring of the bleed air distribution system

The bleed air distribution system consists of a duct system which conveys the hot bleed air to the various consumers (wing de-icing, tail de-icing, air-conditioning packs etc.). Temperature-sensitive loops[6] run along the ducts which activate a warning light in the cockpit if a duct ruptures. In certain cases, the bleed air supply is automatically stopped.

The temperature monitoring system of the bleed air distribution system includes the left and right air supply.

In the present case a leak occurred in the right air supply, more specifically at the transition from the engine 4 pylon to the wing (cf. Annex 10).

This had the following consequences:

- the eng 3 air valve was closed
- the eng 4 air valve was closed
- the right wing inner valve was closed
- the right wing outer valve was closed
- the tail valve 2 was closed
- the pack 2 valve was closed

[4] The pressurisation controller is integrated into the pressurisation control panel.

[5] The combination of the lack of an air supply and the above-mentioned natural leakage resulted in a relatively high rate of climb in the cabin.

[6] These loops are temperature-dependent electrical resistors. A warning is triggered when a defined resistance value is reached.

The following lights flashed on the glareshield panel, and at the same time a single chime sounded:

- the amber attention getting light left
- the amber attention getting light right

The following lights illuminated on the central warning panel (CWP):

- the AIR SUPPLY warning light (cf. Annex 6)
- the AIR COND warning light (cf. Annex 6)
- the ICE PROT warning light (cf. Annex 6)

The following lights illuminated on the air supply panel:

- the R ZONE HI TEMP warning light (cf. Annex 7)
- the ENG 3 AIR VALVE warning light (cf. Annex 7)
- the ENG 4 AIR VALVE warning light (cf. Annex 7)

The following lights illuminated on the ice protection panel (lower part):

- the R INNER VALVE warning light (cf. Figure 2).
- the R OUTER VALVE warning light (cf. Figure 2).
- the Tail Valve 2 warning light (cf. Figure 2).

The following light illuminated on the airconditioning panel (lower part):

- the PACK 2 VALVE warning light (cf. Figure 1).

In summary: the air supply to the cabin failed completely, because pack 1 had been deactivated before take-off. The right-wing de-icing system also failed.

1.6.2.5 Wing de-icing system

The purpose of the wing de-ice and wing anti-ice system is to protect the leading edges of the wings from icing. To achieve this, hot compressed air (bleed air) is branched off from the engine compressors and conveyed through a system of ducts to the space behind the leading edges of the wings. There are so-called piccolo tubes[7], through which the hot air is blown onto the surfaces to be de-iced.

A distinction is made between an ice-prevention system (anti-ice system) and an ice-removal system (de-ice system). The wing anti-ice system extends over the entire length of the wing. The wing de-ice system covers only the inner part. The bleed air from two engines respectively is combined and conveyed via valves and the piccolo tubes.

The outer wing anti-ice[8] switch in Figure 2 actuates the valves for the wing anti-ice system in the left and right wings. The inner wing de-ice switch actuates the two valves of the wing de-ice system.

The warning lights above the switches illuminate if one of the valves is automatically closed. In the present case the two valves in the right wing and one valve in the tail were closed automatically as a result of a leak in the duct system (cf. Chapter 1.6.2.4).

[7] The piccolo tube has two rows with small holes in order to distribute the air optimally.

[8] One refers to outer wing anti-ice even though the system covers the entire wing.

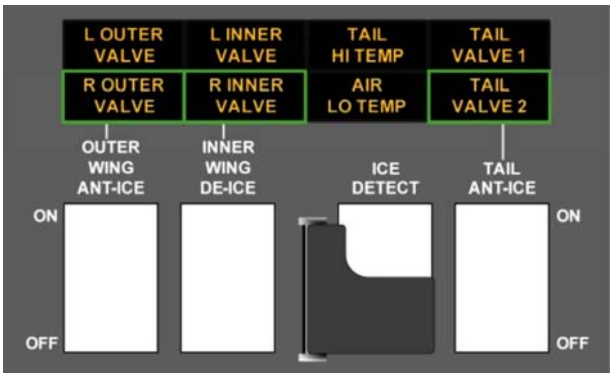


Figure 2: Ice protection panel (lower part).

1.6.2.6 Oxygen system for passengers and cabin crew

The oxygen system for passengers and cabin crew includes a number of boxes each with a chemical oxygen generator and two to four oxygen masks. These boxes are located above the passenger seats, in the toilets and at the cabin crew's workstations. Normally the boxes are covered by a lid and the masks are not visible.

In the event of a drop in pressure the cabin altitude increases and the masks are automatically released from the boxes when a cabin altitude of 13 250 ft (4039 m) is exceeded. This activation is indicated in the cockpit.

If automatic ejection of the masks fails, they can be triggered manually from the cockpit. It is also possible to open an individual box in the cabin. In the present case the cabin crew made use of this option because one of the boxes did not open by itself.

To activate the chemical oxygen generator, it is necessary to pull on one of the corresponding masks from the box. The oxygen then flows to all the masks from that box. The process cannot be reversed. An oxygen generator delivers oxygen for 13 or 22 minutes, depending on the type. Within this time the aircraft must descend to a safe altitude.

A chemical reaction takes place in the oxygen generator. As a result of this process, the generator is heated and a bluish haze may form around the device.

Passengers are informed about using the oxygen masks before each flight in accordance with the regulations.

In order that the crew can move about freely, portable oxygen masks are also available.

1.6.2.7 Oxygen system for the cockpit crew

In an emergency, the cockpit crew obtains oxygen from an oxygen cylinder. This can be refilled via a filler nozzle in the forward cargo hold. The oxygen pressure is regulated via a pressure regulating valve. The oxygen flow to the cockpit can be shut off by means of a main valve. The pressure in the cylinder can be monitored from the cockpit (cf. Figure 3).

The system supplies oxygen to three workstations in the cockpit. The oxygen masks are equipped with microphones, to enable the crew to communicate with each other and by radio.

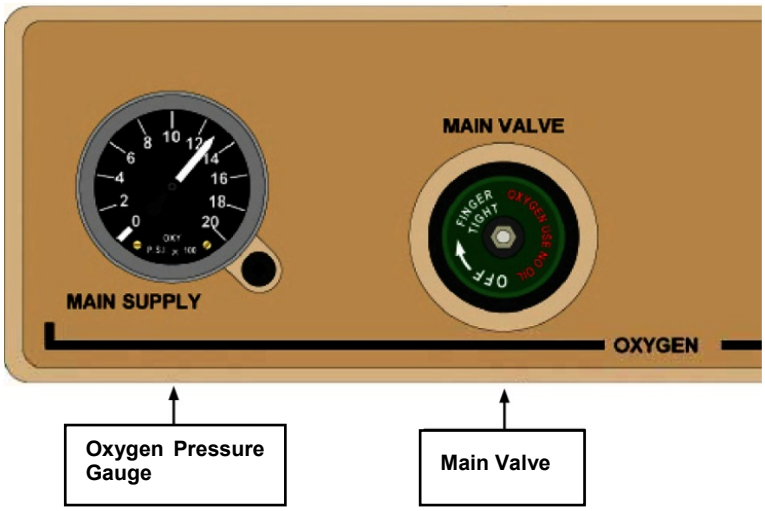


Figure 3: Right oxygen panel with main valve and pressure gauge.

1.6.2.8 Warning in the event of a pressure loss inside the aircraft

The air pressure in the aircraft is regulated by the air conditioning system (cf. Chapter 1.6.2.3). The cabin altitude can be set on the pressurisation control panel (cf. Annex 9). The current cabin altitude is displayed on the cabin triple indicator (cf. Figure 4). The pressurization controller is programmed so that the maximum permissible differential pressure (outside/inside) is not exceeded.

If a technical problem causes the cabin altitude to increase to over 9300 ft (2835 m), the CABIN HI ALT warning light illuminates in red on the central warning panel (CWP) and a triple chime sounds. In the present case, the pressure in the cabin, at the time of the failure of the cabin pressurisation system, corresponded to an altitude of approximately 7000 ft (2134 m).

If the cabin altitude continues to rise to over 13 250 ft (4039 m), the oxygen masks in the cabin are deployed automatically.

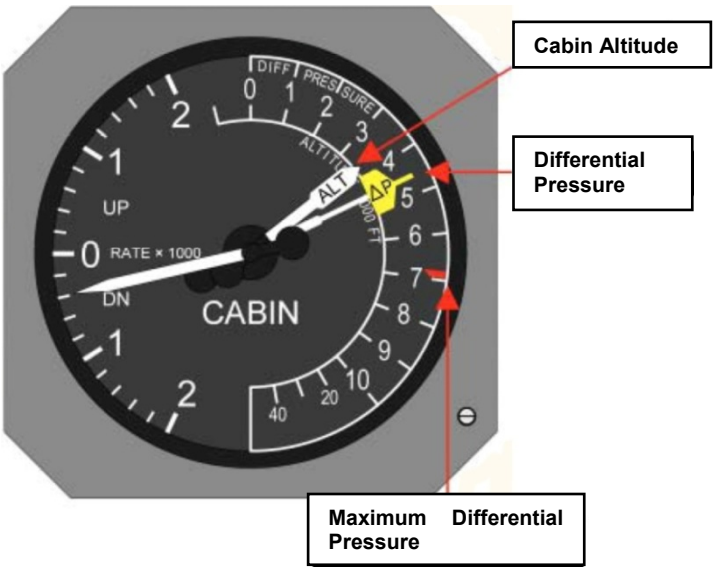


Figure 4: Cabin triple indicator

1.6.2.9 Automatic announcement

If the oxygen masks are deployed in the passenger cabin, the public address system in the cabin issues an automatic announcement (pre-recorded announcement system) with an instruction as to how to use the masks. The announcement is intended to help passengers to remain calm. In the present case, the system did not work, so the announcement had to be made by the cabin crew.

1.6.2.10 System availability on take-off of flight LX 456

On 2 July 2012, immediately before flight LX 456, pack 1 of the air conditioning system was deactivated. According to the minimum equipment list (MEL) this allowed operation for 72 calendar hours with the remaining air conditioning pack 2.

The auxiliary power unit (APU) had been out of service since 26 June 2012 because of an oil leak.

The flight guidance system (FGS) 2 had been listed since 26 June 2012 as INOP (inoperative) in the deferred defect list (DDL).

Aircraft HB-IXW accordingly took off on flight LX 456 in accordance with the MEL, with pack 1 deactivated, APU deactivated and FGS 2 deactivated.

1.6.2.11 System fault as the trigger for the serious incident

The temperature monitoring system of the bleed air distribution system is divided into a left and a right zone of the aircraft.

In the present case a leak occurred in the right aircraft zone, more specifically at the transition from the engine 4 pylon to the wing.

This triggered the closing of various valves and various warning lights illuminated (cf. Chapter 1.6.2.4).

A broken clamp, part number P/N 10A222-200-95, was responsible for the leak (cf. Annexes 10 and 11).

1.6.3 Technical measures immediately after the serious incident

The broken clamp P/N 10A222-200-95 was replaced and a duct leak check was carried out.

At the rear left flight attendant station, a fault in the electrical wiring on the container for oxygen masks was repaired.

All oxygen generators and oxygen masks were replaced and a passenger mask dropout test was performed. In this test the masks on seat rows 1DEF and 18DEF did not deploy. At these positions, the containers for the oxygen masks were replaced.

When the oxygen masks deployed, the pre-recorded announcement did not work. After landing, a functional test was performed, during which the system worked perfectly.

1.7 Meteorological information

1.7.1 General meteorological situation

A narrow ridge of high pressure extended from northern Spain over northern Germany as far as Poland. At high altitude, a ridge extended from Sicily to north-western Russia.

1.7.2 Weather in the area of the Rolampont (RLP) beacon

A broad zone of cloud associated with a warm front was moving from the French Alps to the Baltic. In the area of the Rolampont omni-range radio beacon, satellite data showed a radiation temperature of the cloud surface of -15°C to -20°C.

A comparison with the midday radiosonde ascents from Payerne and Idar-Oberstein shows that this corresponded to a cloud ceiling above western Switzerland of 20 000 to 22 700 ft AMSL, and above Rhineland-Palatinate from 18 800 to 21 200 ft AMSL. According to the crew's statement the aircraft was still in cloud at FL259.

The Idar-Oberstein radiosonde indicated wind at FL 250 from 195° at 60 kt. Over Payerne, the wind in the altitude interval around the same flight level was from 180° at 45 kt.

The comparison with data from the GFS weather forecasting model indicates that an extrapolation of the radiosonde data at the location of the Rolampont beacon is admissible.

Weather/cloud	in cloud
Wind	195 degrees / 55 to 60 kt
Temperature/dewpoint	-28 / -28 °C
Hazards	none

1.7.3 Astronomical information

Position of the sun	Azimuth: 137 Elevation: 60
Lighting conditions	Daylight

1.7.4 Weather report for Zurich Airport

On 2 July 2012, shortly before the 10:50 UTC issue time of the aerodrome weather report, the following weather conditions were observed at Zurich-Kloten airport:

Wind	from 080 degrees at 10 kt
Meteorological visibility	10 km or more
Cloud	1-2/8 at 1200 ft above aerodrome level (AAL)
	5-7/8 at 1800 ft AAL
Temperature	19 °C
Dewpoint	15 °C
Atmospheric pressure QNH	1016 hPa, pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere.
Land weather forecast	No significant changes in the weather to be expected in the two hours following the weather observation.

1.8 Aids to navigation

All navigation aids were in normal operation at the time of the serious incident and were fully available.

No faults were reported by the crew.

1.9 Communications

Radio communications between the pilots and Zurich ATC took place correctly and without difficulties.

Radio communications between the pilots and Reims Control ATC on the 134.405 MHz frequency took place correctly. However, after the frequency change to the 134.960 MHz sector, flight LX 456 (Swiss 473F) had not reported to the latter until the request for a clearance to descend.

From 10:09:40 UTC, after oxygen masks had been donned until flight level FL100 had been reached at 10:15:50 UTC, radio communications for the crew as well as the air traffic control officers became considerably more difficult. The air traffic control officer had to ask back several times, as intelligibility with a mask in place was very poor. On the 134.960 MHz frequency, there was constant radio communication. This led in some cases to simultaneous transmissions, which further impeded intelligibility. It was a challenge for the crew to communicate their emergency situation.

At 10:14:46 UTC there was a request to change to the 132.100 MHz frequency (Paris Control). Here, too, intelligibility with a mask in place was poor. At 10:15:33 UTC, this was manifested, following a message from the crew, when the air traffic control officer responded as follows: *"Swiss four seven three foxtrot, I am sorry, I can't hear you very well, could you speak slowly please?"* After this radio call the crew removed their oxygen masks and this resulted in more intelligible communication.

Aviation safety was not adversely affected at any time by the communication difficulties.

1.10 Flight recorders

1.10.1 Flight data recorder

Type	Solid state flight data recorder (SSFDR)
Manufacturer	Honeywell
Serial number	3737
P/N (part number)	980-4700-003
Number of parameters	64
Recording medium	non-volatile memory
Duration of recording	approx. 50 hours

The flight data recorder data was recorded in full and could be analysed.

1.10.2 Voice recorder

Since the remaining flight time after the serious incident was longer than 30 minutes, the relevant recordings had been overwritten.

1.11 Wreckage and impact information

Not affected.

1.12 Medical and pathological information

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

1.13 Fire

Not affected.

1.14 Survival aspects

Not affected.

1.15 Organisational and management information

1.15.1 Airline operator

At the time of the serious incident, the operator Swiss European Air Lines was a wholly owned subsidiary of Swiss International Air Lines. The latter had decided in spring 2005 to hive off regional traffic to a separate operating company.

The Federal Office of Civil Aviation (FOCA) gave Swiss European Air Lines approval to operate on 1 November 2005. Swiss European Air Lines conducted so-called "wet lease" flights on behalf of the parent company Swiss International Air Lines. All aircraft from the regional fleet of Swiss International Air Lines were transferred to the new company.

1.16 Additional information

1.16.1 Previous incident

On 4 June 2012 on a flight involving the same aircraft, a fault occurred in the bleed air system during a climb. Then too the "R ZONE HI TEMP" warning light illuminated in the cockpit. The flight was continued.

After landing the latch "PYLON #4 OVERHEAT" was set on the maintenance panel. During a leak check it was then established that the duct to the right leading edge of the wing was broken. Several seals had to be replaced or correctly fitted.

Since a virtually identical failure occurred on 2 July 2012 to the bleed air system, it cannot be ruled out that over torqueing of a fastener occurred during these works. This might have caused failure of the de-icing duct clamp.

1.16.2 Procedure for emergency descent

The section entitled *"Decompression"* of the airline's operational manual A (OM A) states, among other things *"...turn away from the assigned route or track with due consideration to terrain...".*

In the airline's operations manual B (OM B) there were no aircraft-specific instructions or instructions deviating from the OM A. Reference was merely made to the following sections in the QRH *"Emergency Descent after Pressurization Failure"* and *"Cabin High Altitude"* (cf. Annexes 4 and 5). In these checklists for emergency procedures, no reference was made to the flight path.

2 Analysis

2.1 Technical aspects

2.1.1 Air conditioning system

The aircraft was taken over by the crew for flight LX 456 according to the minimum equipment list (MEL). This allows operation of the aircraft with only one air conditioning pack, taking into account operational requirements, for a maximum of 72 calendar hours.

At 10:08:22 UTC, during the climb to FL 244 (7437 m), as a result of a leak in the right air supply system various valves were closed (cf. Chapter 1.6.2.4). Consequently, the bleed air supply to air conditioning pack 2 was cut off. Since a cross-feed from the left air supply system is not possible and also since airconditioning pack 1 was inoperative, the entire air conditioning system failed.

If one assumes that the pressurisation control panel was working in AUTO mode, the rate selector was at the detent and the cabin altitude was preselected for a cruising altitude of 30 000 feet, then the cabin altitude at this time was approximately 7000 feet. At a rate of climb of 525 ft/min, this cabin altitude would have been attained some 10 minutes after take-off.

The cabin altitude began to increase immediately after the serious incident. According to information from the operator's management, this increases at about 2000 ft/min. A corresponding recording does not exist. Compared to newer aircraft, this rate of climb is relatively high. However, taking into account natural leaks on an aging aircraft, the high rate is explicable.

At 10:09:45 UTC, at an altitude of 25 100 feet (7650 m), the CABIN HI ALT warning light illuminated. In the interim, the cabin altitude had increased to 9300 feet (2835 m). At 10:11:05 UTC, at an altitude of 25 900 feet (7894 m), the crew initiated the emergency descent. This was carried out at an average rate of descent of 3600 ft/min.

During the emergency descent, after the cabin altitude had increased to 13 250 feet (4039 m), the passenger oxygen masks were deployed. This could not have been prevented, even at a higher rate of descent of the aircraft, owing to the cabin's relatively high rate of climb.

Finally, it can be said that during the serious incident all relevant components of the air conditioning system functioned according to there design.

2.1.2 Aircraft de-icing system

According to the crew's statement, during the climb the wing, tail, and engine de-icing systems were switched on.

At 10:08:22 UTC, as a result of a leak in the right air supply, various valves were closed (cf. Chapter 1.6.2.4). As a result, the supply of hot air to the right wing was stopped and its de-icing was no longer guaranteed.

The tail de-icing system includes redundancy. This means that, although the tail valve 2 was closed, the tail continued to be supplied with hot air from the left air supply System.

The de-icing of the engine intakes is associated with an independent bleed air zone and was not affected by the described defect.

On the basis of the meteorological data, there was no acute risk of icing in the relevant area. However, the aircraft was in cloud.

2.1.3 Auxiliary power unit

The auxiliary power unit (APU) had been out of service since 26 June 2012. The following was noted in the technical logbook: *"leakage on APU oil drain".*

In accordance with the minimum equipment list (MEL), the aircraft could be operated for a maximum of 10 days without the APU, taking into account operational requirements. This time limit had not been reached by 2 July. The MEL allows deferment of a major repair or of the replacement of a unit until a fairly long period on the ground.

The non-availability of the APU had no effect on the course of the serious incident, as it would not have been able to be started at cruising altitude (above 15 000 ft).

2.1.4 Passenger masks and oxygen generators

In normal operation, the oxygen masks in the cabin are deployed by means of an electrical signal. If this system fails, the oxygen masks can be deployed manually; in the present case this is what was done by the cabin crew for seat row 1DEF.

Since automatic activation of the oxygen masks in normal flight operations rarely occurs, this function must be tested periodically; this takes place according to the maintenance schedule after every 10 000 cycles. This check also includes the pre-recorded announcement.

On older aircraft, the oxygen was routed from a central location via a duct system to the passengers. This method represented a considerable potential risk. Today, oxygen is usually generated by oxygen generators located directly above the passenger seats. These are heated considerably as a result of the chemical reaction in the oxygen generators. After a while, this may cause a slight haze. This is normal, but rather unpleasant for some passengers, because they believe it is smoke.

2.2 Human and operational aspects

2.2.1 Conduct of the cockpit crew during the serious incident

The take-off from Zurich and the climb were uneventful until the first warning lights illuminated at FL 244. Communication with all ATC sectors was normal until this point. After several warning lights illuminated, the crew realised that the cabin pressurisation system had failed completely and that as a result the cabin altitude would increase. Whilst the aircraft was still climbing, the "*Emergency Descent after Pressurization Failure"* checklist was initiated. The crew then requested clearance to descend. This unexpected call with special content *("...foxtrot, requesting descent, we have a pressurization problem")* caused the air traffic control officer to query this; the crew did not give a full reply. Presumably, the reason for this involved procedures in the cockpit demanding higher priority for safe flight management.

Shortly afterwards, the CABIN HI ALT warning light illuminated. The crew then donned their oxygen masks and reported at FL 256 *"mayday... mayday... emergency descent to flight level one hundred"*.

The "*Emergency Descent after Pressurization Failure*" checklist specifies in its first section (memory items) that a descent should be initiated immediately. More than two and a half minutes elapsed from the appearance of the first warnings to the beginning of the descent. This can be explained in part by the communication difficulties. Since this was not a case of rapid decompression and since, as a

precaution, the crew had donned their oxygen masks, this time lag had no negative effect.

The crew's decision not to initiate a heading change before the descent had no consequences, but did not comply with the procedure.

2.2.2 Conduct of the cabin crew during the serious incident

Communication between the cockpit and the cabin crew was ensured at all times.

The cabin crew reacted quickly and appropriately to the problems due to the non-deployment of some masks and the non-functioning automatic announcement.

The assistance and guidance to the passengers was carried out in a professional manner.

2.2.3 Conduct of the operator after the serious incident

The airline operator carried out an operational risk evaluation (ORE) with the aim of improving safety (cf. Chapter 4.2).

In addition, an altitude restriction could be adopted for the operation with only one functioning air conditioning pack. This would shorten the time of an emergency descent to a safe level.

2.2.4 Conduct of air traffic control during the serious incident

2.2.4.1 Reims Control

Up to the time of the serious incident, communication between Reims Control and LX 456 went smoothly. At 10:09:09 UTC, flight LX 456 (Swiss 473F) was handed over by the 133.405 MHz sector to the 134.960 MHz sector, during which, however, it did not report using the standard phraseology for a first call. This first call is generally the time at which the air traffic control officer (ATCO) in the new sector takes over control and therefore the responsibility for the progress of a flight within his airspace. Until then, air traffic control had no reason to assume that serious problems had occurred on the aircraft. The air traffic control officer for the 134.960 MHz sector could not know that the crew had actually switched to his sector's frequency but was busy with priority tasks which allowed no time for communication. At 10:09:40 UTC, when the radio message with the request for a descent clearance because of cabin pressure problems occurred, the air traffic control officer was neither able to determine its origin, nor to comprehend its contents clearly. This consequently led to a query. The response of the crew was incomplete but included part of the radio call sign. The air traffic control officer was now aware that the radio message came from flight Swiss 473F and that it was on his frequency. It was also shown on his radar screen and was expected based on the flight plan data. The short radio silence after this aborted response was used by two other flights for radio communication with the control unit; at one point a simultaneous transmission is audible. This was also noted by the air traffic control officer, who requested a repeat of the radio transmission.

Then, at 10:10:31 UTC, now wearing oxygen masks, the crew of flight Swiss 473F declared an emergency with a radio message, which began *"mayday...mayday"* . This radio message, despite difficult intelligibility due to the wearing of oxygen masks, together with the transponder code A7700 appearing on the radar screen, finally made things clear to the air traffic control officer, who then gave clearance for the descent and a little later handed the flight over to Paris Control.

The fact that the first radio message was not made as an emergency call caused confusion for the air traffic control officer and lead to queries about the situation of flight Swiss 473F. It is possible, had the emergency been declared at the critical moment, no radio communications with other aircraft would have taken place.

2.2.4.2 Paris Control

Although the Paris Control ATCO was expecting the call from flight LX 456, intelligibility was so poor that the latter also had to query several times. When LX 456 reached the safe altitude and the crew removed their oxygen masks, communication was again intelligible and the return flight to Zurich could be initiated without any problems.

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 aircraft flight manual (AFM) at the time of the serious incident.
- The last A-check was carried out on 18 June 2012 at 35 563 cycles.
- Air conditioning pack 1 had been deactivated before flight LX 456.
- At FL 244, in climb, a leak occurred as a result of a broken clamp in the right bleed air supply system (cf. Annexes 10 and 11).
- Subsequently the air supply to air conditioning pack 2 was stopped and the cabin pressurisation system failed completely.

3.1.2 Crew

- 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.

3.1.3 History of the flight

- The commander was pilot flying and the copilot was pilot not flying.
- The take-off in Zurich and the subsequent climb as far as to the Rolampont (RLP) area took place normally.
- Because of a leak in the right bleed air supply system, the R ZONE HI TEMP warning light illuminated and the airconditioning pack 2 was automatically switched off.
- The pressure in the cabin fell and the cabin altitude increased at a rate of approximately 2000 ft/min.
- The crew reported a problem with the cabin pressurisation system to air traffic control and requested clearance to descend.
- Shortly afterwards, the CABIN HI ALT warning light illuminated.
- The crew donned their oxygen masks.
- An emergency was declared and the emergency descent was initiated without altering course.
- During the descent, a change was made to transponder code A7700.
- In the cabin, the oxygen masks were deployed and donned by the passengers and the cabin crew.
- Approximately four and a half minutes after the start of the emergency descent, the aircraft reached the safe flight level FL 100 (3048 m).
- The emergency descent was made with the autopilot engaged.

- The cockpit crew informed the chief cabin attendant that the aircraft was at a safe altitude and that the oxygen masks could now be removed.
- After a thorough assessment of the situation, the crew decided to fly back to Zurich, where the landing took place at 10:57:18 UTC.

3.1.4 Air traffic control

- The air traffic control officers for the sectors involved assisted the crew of LX 456.

3.1.5 General conditions

- At the time of the serious incident the engine and wing de-icing systems were switched on.
- On the basis of the meteorological data, there was no acute risk of icing in the relevant area.
- The communication between the flight crew and air traffic control was affected by the wearing of oxygen masks.
- The slight haze generated in the cabin as a result of a chemical reaction in the oxygen generators led to anxiety among several passengers.

3.2 Causes

The serious incident is attributable to the fact that after a defect in the right bleed air system the cabin pressurisation system failed completely at FL 244 (7437 m) and the crew were forced to make an emergency descent to a safe altitude.

The fact that airconditioning pack 1 had been deactivated prior to the flight contributed to the serious incident.

4 Safety recommendations and measures taken since the serious incident

4.1 Safety recommendations

None.

4.2 Measures taken since the serious incident

The airline operator carried out a so-called Operational Risk Evaluation (ORE) in order to investigate the risks which are association with "*single air conditioning operation*". This evaluation included the AVRO 146-RJ100 and Airbus A320 series aircraft.

In the case of the AVRO 146-RJ100 aircraft, the analysis led to a more restrictive application of the minimum equipment list (MEL), as follows:

"....*operation with only one airconditioning pack operative is not permitted ex* ZRH, GVA and BSL".

"*dispatch ex outstation according MEL possible after contact of flight operation* (FDO)".

This restriction applies provisionally until September 2013.

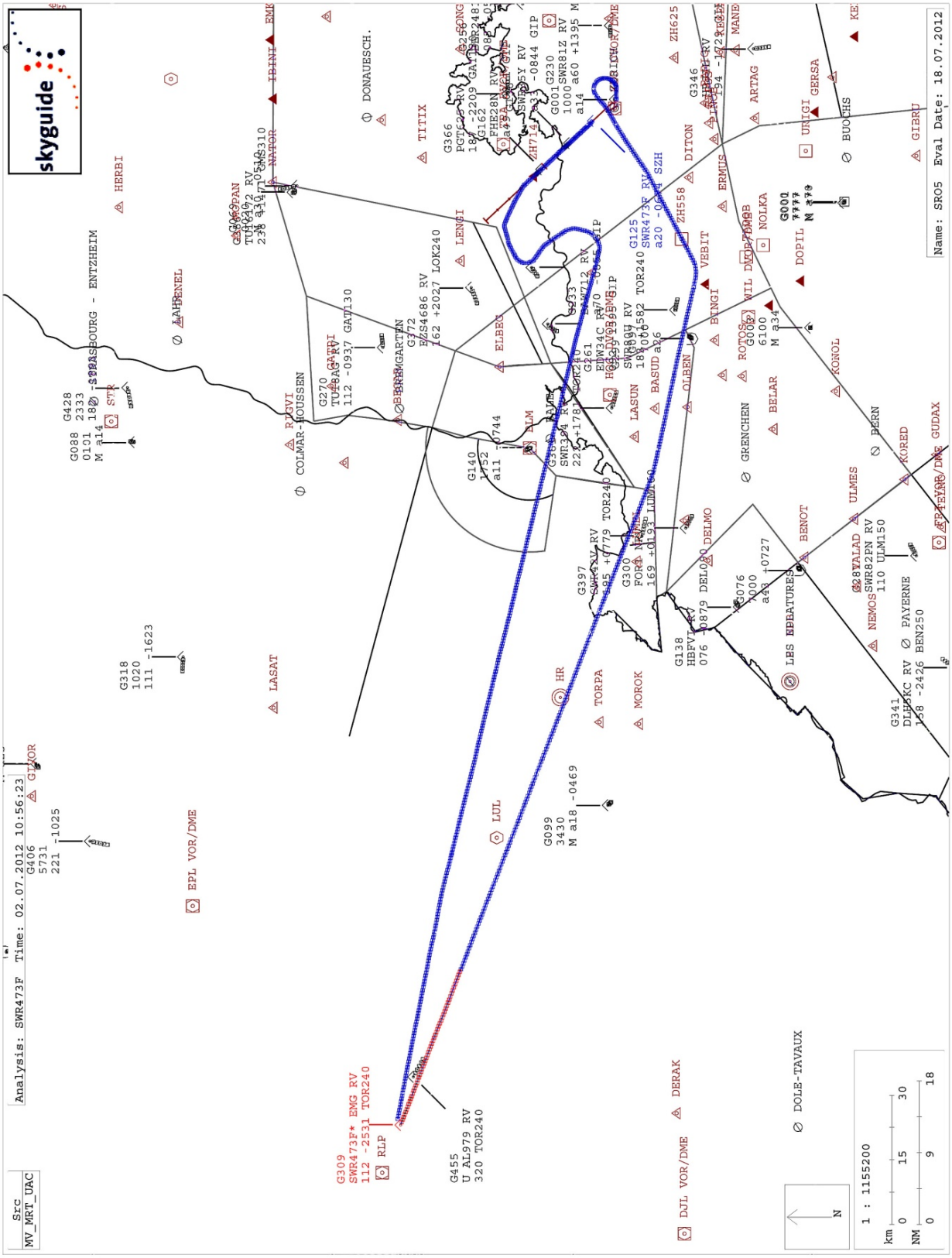
Payerne, 10 December 2013 Swiss Accident Investigation Board

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).

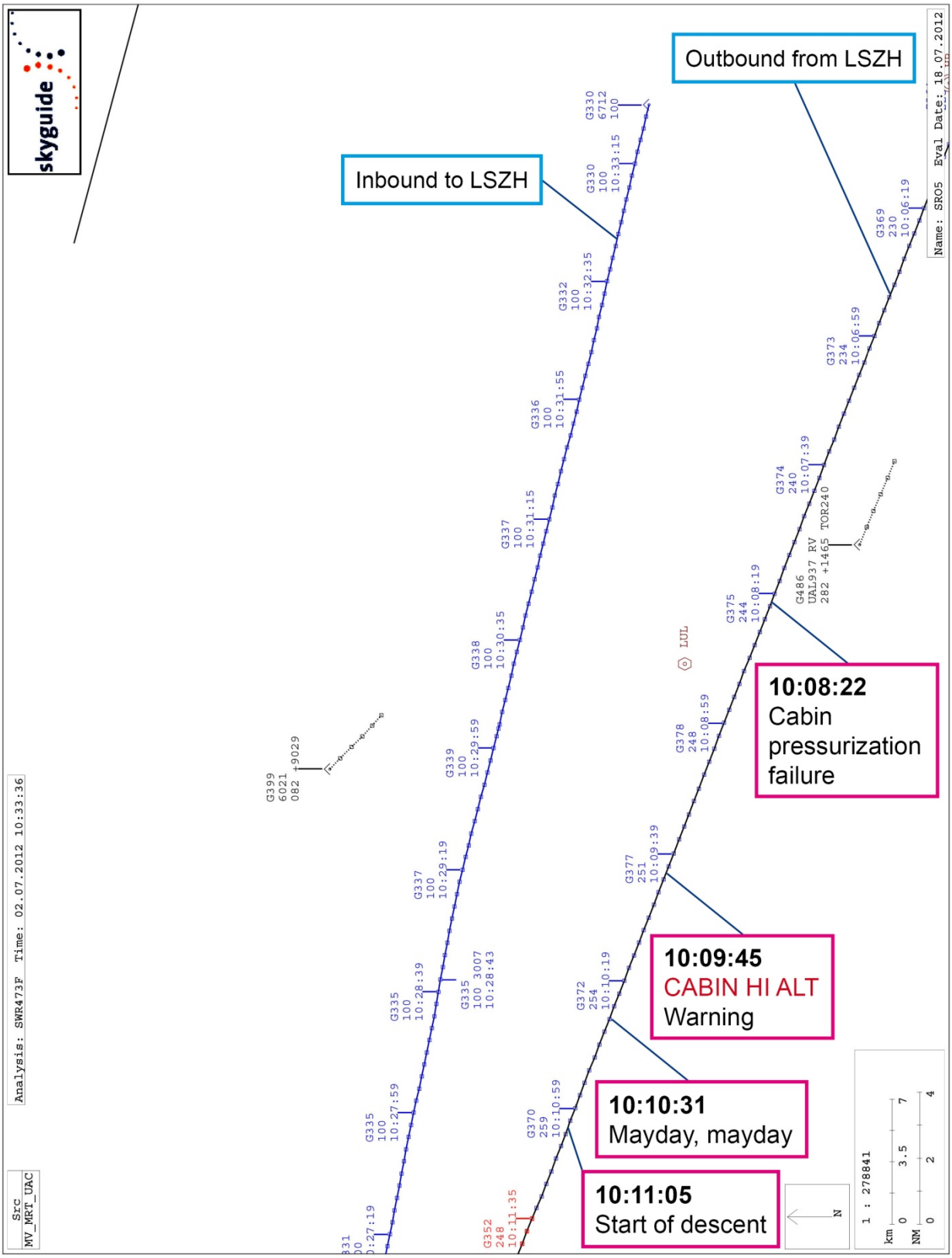
Berne, 12 December 2013

Annexes

Annex 1: Overall progression of the flight (LSZH – LSZH)



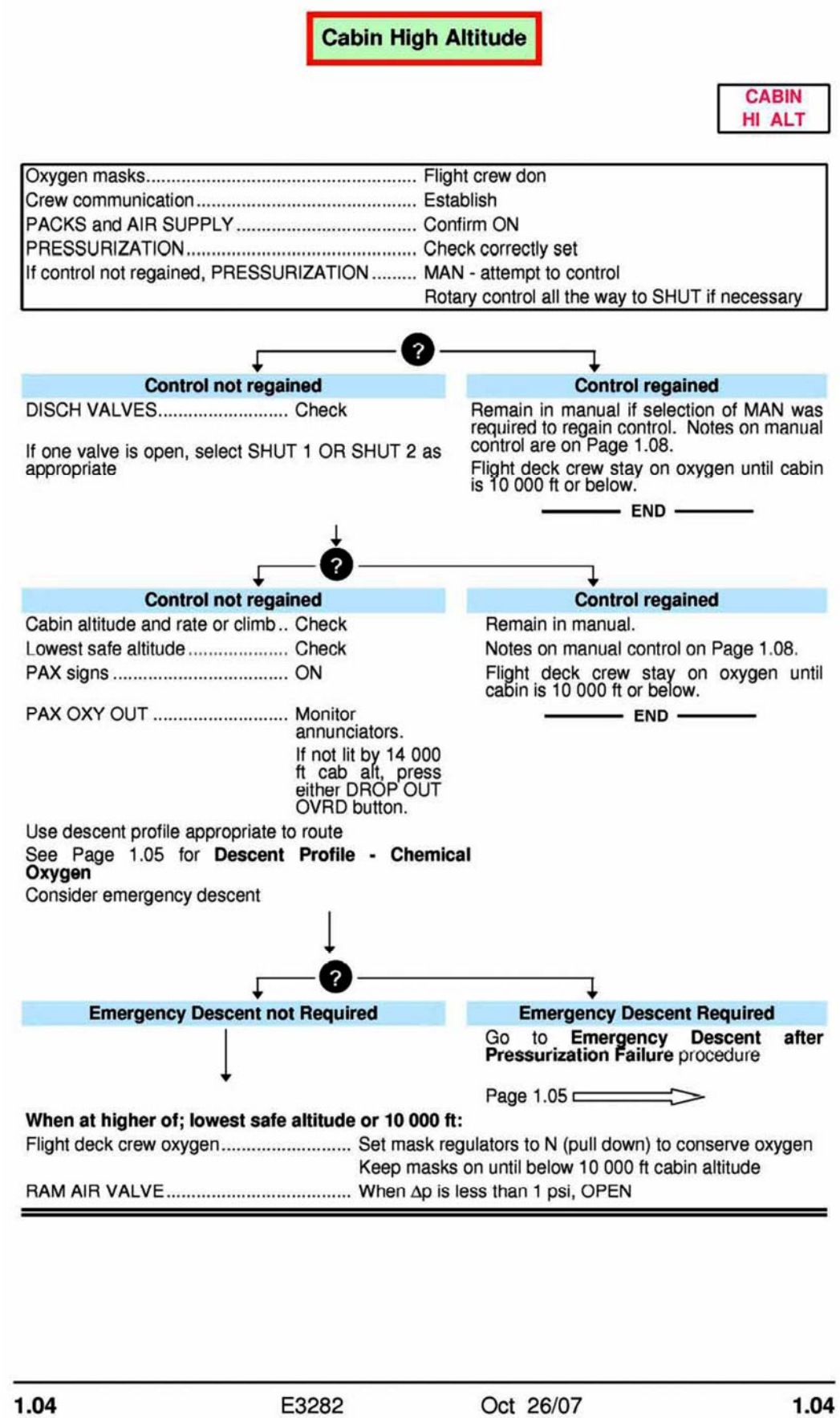
Annex 2: Progression of the flight during the serious incident



Annex 3: Chronological sequence of major events

UTC	Flight phase	Event	Action
09:47	Take-off in Zurich	Flight LX456 (HB-IXW) takes-off	
10:08:22	FL244, climb (AP on; AT on, Hdg. 287°, 260 KIAS)	The following warning lights illuminate: **AIR SUPPLY, AIR COND, ICE PROT, R ZONE HI TEMP, ENG 3 AIR VALVE, ENG 4 AIR VALVE, R INNER VALVE, R OUTER VALVE, PACK 2 VALVE** Cabin altitude starts to rise	
10:09:40	FL250, climb		Crew request clearance to descend
10:09:45	FL251, climb	The following warning lights illuminate: **CABIN HI ALT** + *red attention-getting lights* + *triple chime*	Crew starts processing checklist *"Cabin Hi Altitude"*
			Crew don oxygen masks
10:10:31	FL256, climb	Communication with Reims Control with donned oxygen masks is difficult. Other radio traffic also impedes comprehension.	Crew report: *"Mayday, mayday ... emergency descent to flight level one hundred."*
10:11:05	FL259, start of descent		Crew initiates emergency descent: AP LVL-CHG Mach to FL100, AT off, air brakes out
10:11:35	FL244, descent	(AP on, AT off, Hdg. 285°, 264 KIAS)	Crew changes transponder code to A7700
	FL238, descent	Passenger oxygen masks are deployed	Cabin crew assist passengers
10:11:49	FL231, descent	Communication with Reims Control still difficult. Crew repeats emergency call.	Crew report: *"We have to descend to one hundred, mayday, mayday."*
10:11:54	FL227, descent		Reims Control reports: *" difficulty to understand you, so you may descend to flight level one hundred, if you have to."*
10:14:46	FL120	Frequency change: 134.960 (Reims) – 132.100 (Paris)	
10:15:40	FL100,	LX456 reaches flight level FL100 and continues flying towards Rolampont (RLP)	
10:17:27	FL100	LX456 reports intention to turn back and return to Zurich	
10:18:32	FL100	LX456 turns left and flies towards Basel	
10:20:24	FL100		Crew report: *"…no assistance needed …flying without pressurization."*
10:57:18	Landing in Zurich	Uneventful landing	

Annex 4: Emergency checklist – Cabin High Altitude



Cabin High Altitude

CABIN HI ALT

Oxygen masks	Flight crew don
Crew communication	Establish
PACKS and AIR SUPPLY	Confirm ON
PRESSURIZATION	Check correctly set
If control not regained, PRESSURIZATION	MAN - attempt to control
	Rotary control all the way to SHUT if necessary

?

Control not regained

DISCH VALVES ..... Check

If one valve is open, select SHUT 1 OR SHUT 2 as appropriate

Control regained

Remain in manual if selection of MAN was required to regain control. Notes on manual control are on Page 1.08.

Flight deck crew stay on oxygen until cabin is 10 000 ft or below.

END

?

Control not regained

Cabin altitude and rate or climb .. Check

Lowest safe altitude ..... Check

PAX signs ..... ON

PAX OXY OUT ..... Monitor annunciators.

If not lit by 14 000 ft cab alt, press either DROP OUT OVRD button.

Use descent profile appropriate to route

See Page 1.05 for **Descent Profile - Chemical Oxygen**

Consider emergency descent

Control regained

Remain in manual.

Notes on manual control on Page 1.08.

Flight deck crew stay on oxygen until cabin is 10 000 ft or below.

END

?

Emergency Descent not Required

Emergency Descent Required

Go to **Emergency Descent after Pressurization Failure** procedure

Page 1.05

When at higher of; lowest safe altitude or 10 000 ft:

Flight deck crew oxygen	Set mask regulators to N (pull down) to conserve oxygen
	Keep masks on until below 10 000 ft cabin altitude
RAM AIR VALVE	When Δp is less than 1 psi, OPEN

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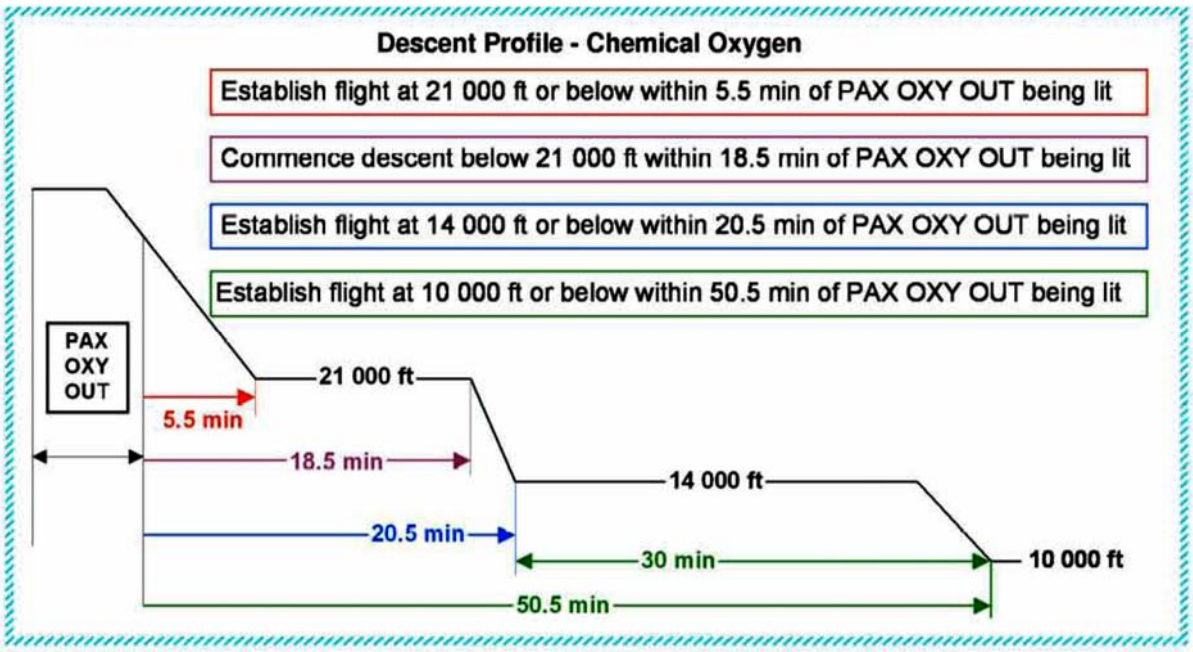
Annex 5: Emergency checklist – Descent after Pressurization Failure

Emergency Descent after Pressurization Failure

Emergency descent	Announce
Thrust Levers	Flight idle
Target speed	Announce - M_{MO}/V_{MO} or 0.6 M/240 kt If structural integrity in doubt, do not exceed 0.6 M/240 kt and limit "g".
Airbrake	OUT
Establish flight at 10 000 ft or the lowest safe altitude if higher	

CONT IGN A and B	ON
Transponder	As required
When at higher of; 10 000 ft or lowest safe altitude:	
Flight deck crew oxygen	Set mask regulators to N (pull down) to conserve oxygen Keep masks on until at or below 10 000 ft cabin altitude
RAM AIR VALVE	When Δp is less than 1 psi, OPEN
CONT IGN	As required



Loss of Control of Pressurization

If CABIN HI ALT caption illuminates at any time in the following procedure, use Cabin High Altitude procedure on Page 1.04

ENG AIR ..... Confirm serviceable valves ON
PACKS ..... Confirm serviceable packs ON
PRESSURIZATION..... Confirm correctly set

?

Control not regained

PRESSURIZATION..... MAN
Attempt to control - SHUT if necessary

Control regained

END

?

Control not regained

Check discharge valve positions
If one valve is open, select it SHUT

Control regained

Continue in manual control
Notes on manual control on Page 1.08

END

?

Control not regained

Go to appropriate procedure on Page 1.07

Control regained

Keep the one valve SHUT
Continue in manual control
Notes on manual control on Page 1.08

1.06 E3282 Oct 26/07 **1.06**

Annex 6: Central Warning Panel – Relevant warning annunciators

Notes:

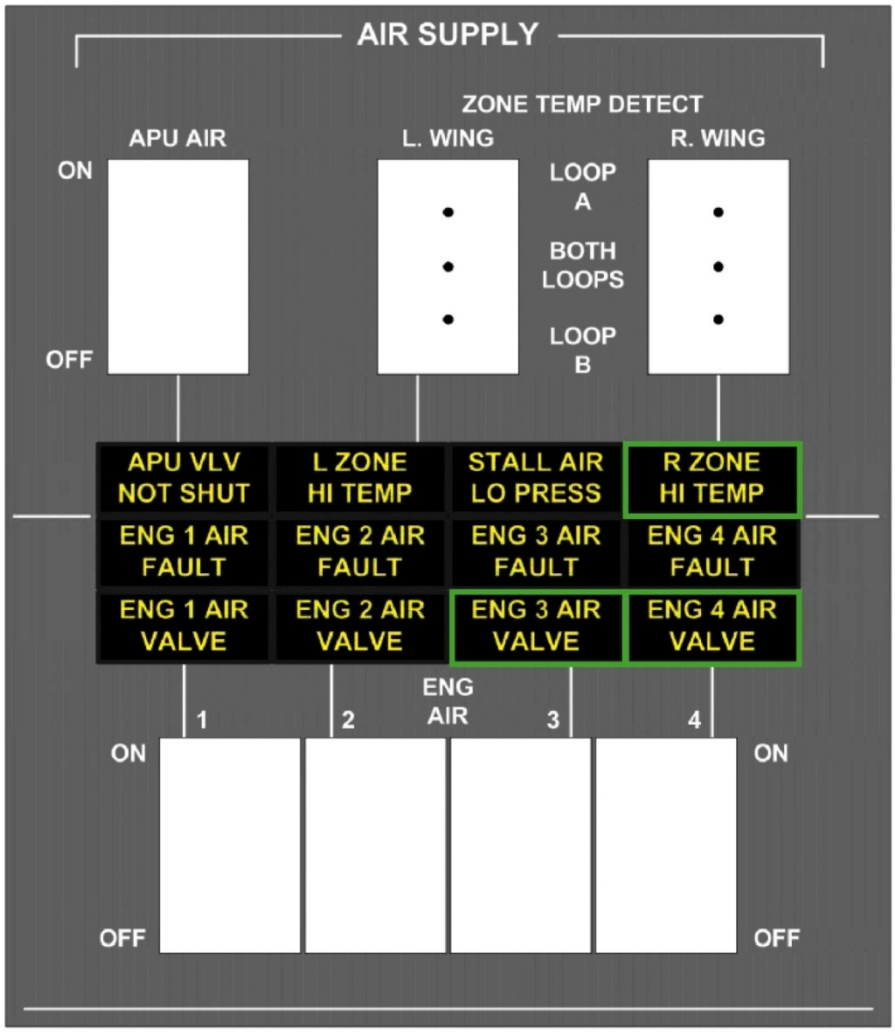
The red warning annunciators are accompanied by a triple chime and two red warning lights left and right on the glareshield panel (attention getting lights).

The amber warning annunciators are accompanied by a single chime and two amber warning lights left and right on the glareshield panel (attention getting lights).

The arrows pointing upwards indicate that other annunciators are displayed on the overhead panel.

Likewise the arrows pointing left and down.

Annex 7: Air Supply Panel – Relevant warning annunciators

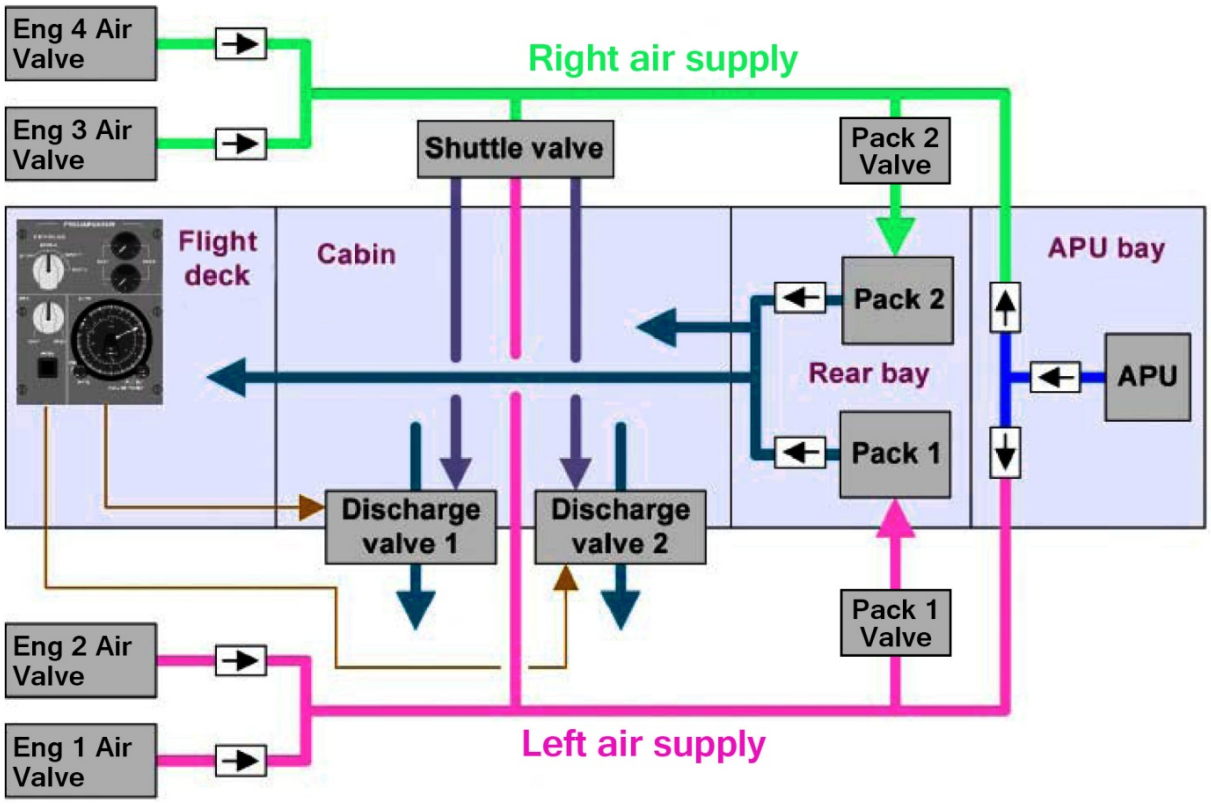


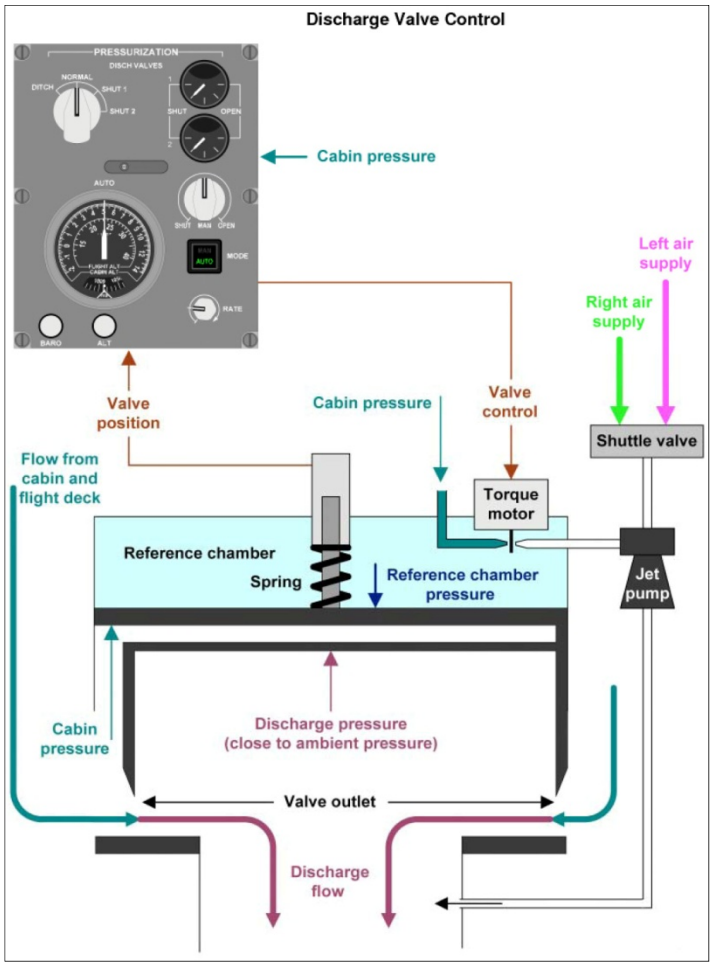
Note:

A leak in the right air supply, more specifically at the transition from the engine 4 pylon to the wing (cf. Annex 10) triggered the **R ZONE HI TEMP** warning annunciator. As a result, the following valves were automatically closed and the corresponding warning annunciators illuminated:

- **ENG 3 AIR VALVE** (cf. Annex 7 and 8)
- **ENG 4 AIR VALVE** (cf. Annex 7 and 8)
- **R INNER VALVE** (cf. Chapter 1.6.2.5)
- **R OUTER VALVE** (cf. Chapter 1.6.2.5)
- **TAIL VALVE 2** (cf. Chapter 1.6.2.5)
- **PACK 2 VALVE** (cf. Chapter 1.6.2.2)

Annex 8: Schematic of the cabin pressurization system





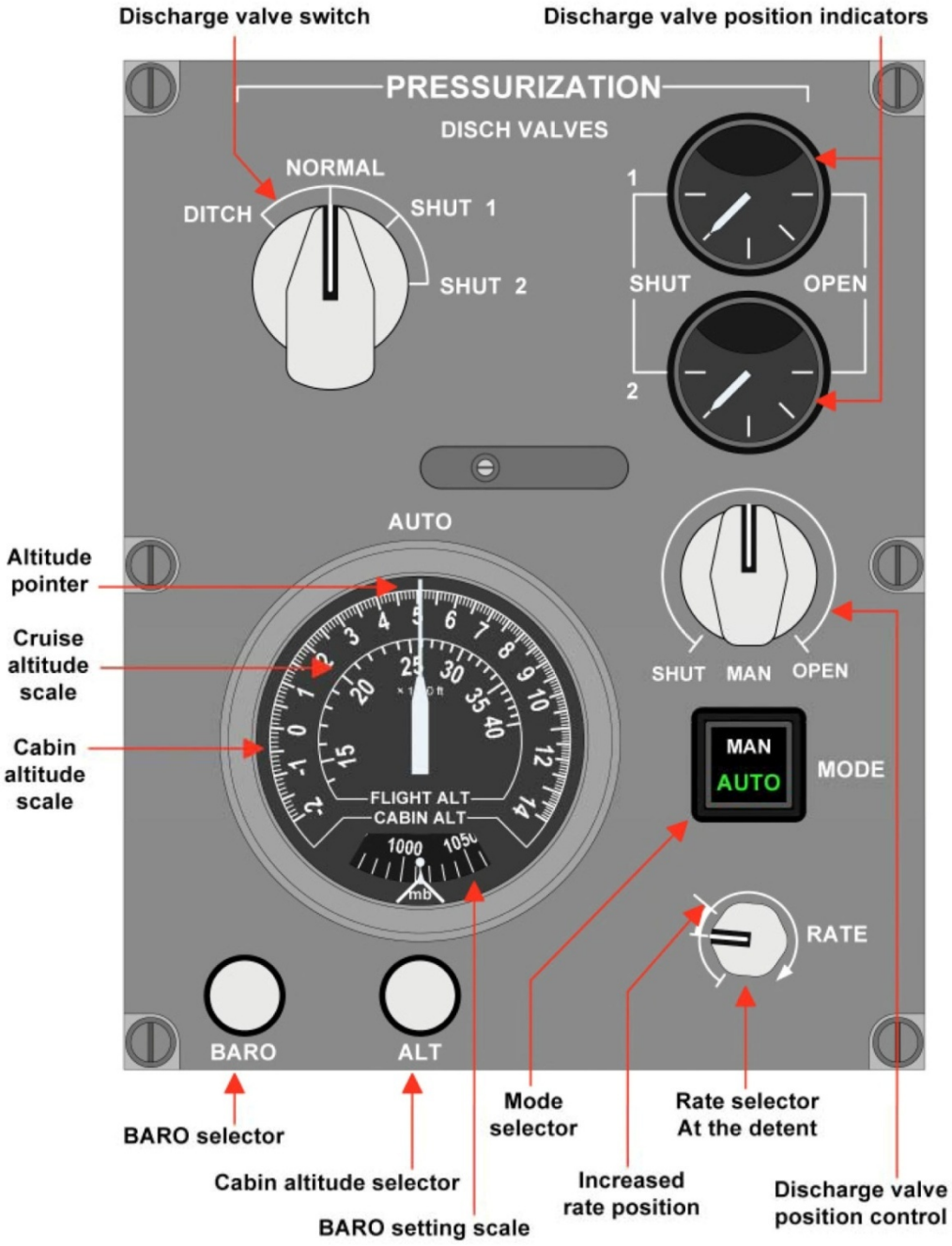
Notes:

The pack 1 valve was closed from take-off and therefore pack 1 was not available for flight LX 456.

A simplified fuctional description of the cabin pressurization system is given in chapter 1.6.2.3.

During the serious incident, the cabin pressurization system was in AUTO mode (cf. Annex 9)

Annex 9: Pressurization control panel



Note:

The investigation assumes the following settings during the serious incident:

Discharge valve switch -- NORMAL

Mode selector -- AUTO

Rate selector -- at the detent

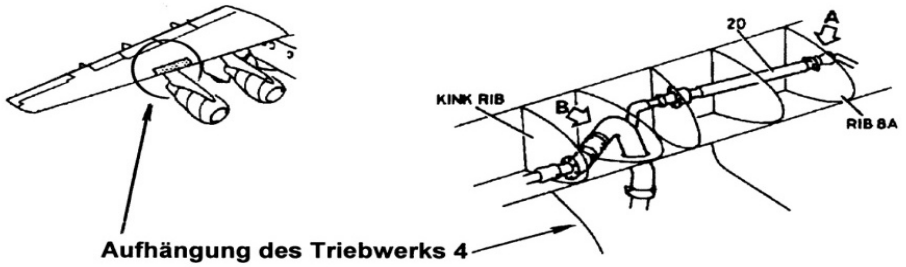
Selected cabin altitude -- 7000 ft

AUTO MODE: When the rate selector is at the detent, the following rates of climb and descent are complied with for the cabin: 525 ft/min climb, 375 ft/min descent.

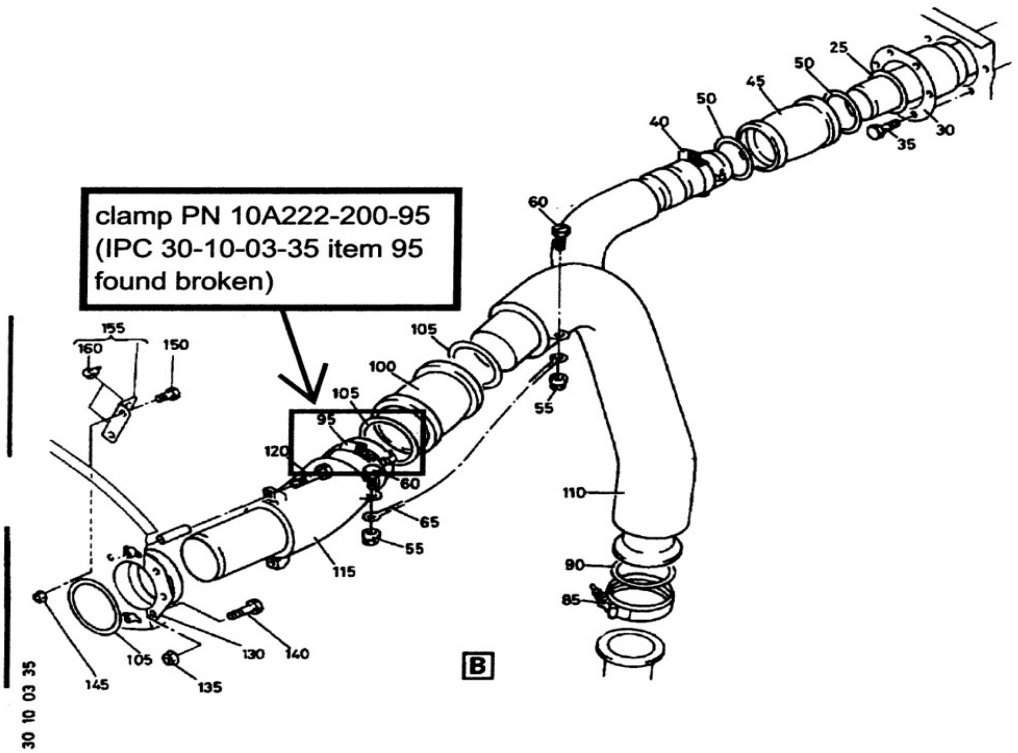
Annex 10: Leaking bleed air duct in the vicinity of engine no. 4

BAE SYSTEMS

BAe 146 SERIES/AVRO 146-RJ SERIES ILLUSTRATED PARTS CATALOGUE



Engine 4 Pylon



DE-ICING DUCT INSTL-WING, RIB 8A TO KINK RIB,RH

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Annex 11: Broken clamp P/N 10A222-200-95