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Aircraft Accident Investigation Bureau AAIB

Final Report No. 1980 by the Aircraft Accident Investigation Bureau

concerning the serious incident

to the AVRO 146-RJ100 aircraft, HB-IXU

operated by Swiss European Air Lines AG

under flight number LX 1105

on 12 December 2006

approx. 20 km north of Kempten (D), FL 200

Bundeshaus Nord, CH-3003 Berne

Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass die Besatzung nach dem Anlassen der Triebwerke die Klima- und Kabinendruckanlage nicht einschaltete und dies während des Steigflugs nicht bemerkte.

Zum schweren Vorfall beigetragen haben:

- Ein defekter *cabin altitude warning switch*, welcher die Warnung CABIN HI ALT nicht auslösen konnte.
- Der Komplexität des pneumatischen Bordsystems nicht angepasste Verfahren und Checklisten.

General information on this report

This report contains the AAIB's conclusions on the circumstances and causes of the serious incident which is the subject of the investigation.

In accordance with Annex 13 of the Convention on International Civil Aviation of 7 December 1944 and article 24 of the Federal Air Navigation Law, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent future 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 Swiss Local Time – LT. At the time of the serious incident, Swiss Local Time corresponded to Central European Time (CET). The relation between LT, CET and UTC (co-ordinated universal time) is:
LT = CET = UTC + 1 hour.

For reasons of protection of privacy, the masculine form is used in this report for all natural persons, regardless of their gender.

Contents

Final Report

Owner	Swiss International Air Lines Ltd., CH-4002 Basle
Operator	Swiss European Air Lines AG, CH-4052 Basle
Aircraft type	AVRO 146-RJ100
Country of registration	Switzerland
Registration	HB-IXU
Location	approx. 20 km north of Kempten (D), FL 200
Date and time	12 December 2006 at 14:55 LT

Synopsis

During a scheduled flight from Munich to Zurich on an AVRO 146-RJ100 aircraft, the crew forgot to switch on the air-conditioning and cabin pressurisation systems after starting the engines. These also remained switched off during the take-off and climb.

When the cabin altitude exceeded a value of approximately 9300 ft, the CABIN HI ALT warning was not triggered because of a faulty cabin altitude warning switch. When the cabin altitude reached values in excess of 13 000 ft, the oxygen masks were deployed. At this time, the aircraft was approximately 20 km north of Kempten (D) at FL 200.

After an emergency descent and once the cabin pressurisation system had been switched on, the aircraft landed in Zurich-Kloten.

Investigation

The serious incident took place at approximately 14:55 LT. The notification was received by the Swiss AAIB at 17:10 LT. After consultation with the German Federal Republic's Federal Bureau of Aircraft Accidents Investigation, the investigation was delegated to the Swiss AAIB and opened on the same day.

The serious incident is attributable to the fact that after starting the engines the crew did not switch on the air-conditioning and cabin pressurisation system and did not realise this during the climb.

The following factors contributed to the serious incident:

- a defective cabin altitude warning switch, which was unable to trigger the CABIN HI ALT warning.
- procedures and checklists which were not adapted to the complexity of the onboard pneumatic system.

Within the framework of the investigation, three safety recommendations were made.

Preliminary remark by the Swiss AAIB

It is worth noting that this serious incident had an initial situation similar to the accident of a Helios Airways Boeing 737-315 that took place on 14 August 2005 in Greece.

1 Factual information

1.1 Pre-flight history and history of the flight

1.1.1 General

The digital flight data recorder (DFDR) recordings, the recordings of radiocommunication traffic, radar data and the statements of crew members were used for the investigation. Throughout the entire flight the copilot was pilot flying (PF) and the commander was pilot not flying (PNF).

The flight was carried out under instrument flight rules.

1.1.2 Preliminary remark

The AVRO 146-RJ aircraft has been in service with the operator since 1990.

In November 2005, the operational procedures regarding checklists were modified. Among other things, during operation of the aircraft a written checklist is now used only on the ground. From take-off to landing, the crew carries out routine manipulations in accordance with defined procedures without a checklist. In this context, cf. section 1.18.1.3.

1.1.3 Pre-flight history

The four crew members of the AVRO 146-RJ100 aircraft HB-IXU began their duty on 12 December 2006 at 06:25 LT in Zurich, in order to fly scheduled flights LX 814 and LX 815 to Hanover (D) and back. Afterwards it was planned to fly the scheduled flights LX 1104 and LX 1105 to Munich (D) and back to Zurich again.

After consulting the usual documentation, the crew prepared the aircraft to carry out all the four flights on HB-IXU.

After the crew had landed under flight number LX 815 from Hanover (D) in Zurich, HB-IXU was prepared for flights LX 1104 and LX 1105. The crew decided to carry 6.5 tonnes of fuel, in order to have onboard the fuel required for the return flight to Zurich.

About an hour later, the AVRO 146-RJ100 flew under flight number LX 1104 from Zurich (LSZH) to Munich (EDDM). During this flight, after landing while leaving the runway, a malfunction of the integrated drive generator (IDG) of engine number 1 was detected. The commander then informed the appropriate Swiss maintenance department in Basle. The latter organised the relevant maintenance company in Munich to undertake the necessary measures and to make the corresponding entry in the deferred defect list (DDL). Under these circumstances, it was possible to use the electrical generator of the auxiliary power unit (APU) instead of the defective engine number 1 drive generator in accordance with the minimum equipment list (MEL). The return flight to Zurich therefore commenced as planned.

1.1.4 History of the flight

According to the operations flight plan (OFP), 3.2 tonnes minimum block fuel was required for the flight to Zurich. No refuelling took place, as the aircraft still had an actual block fuel of 4.7 t. As usual, the return catering was carried on the outward flight.

According to the load sheet, there were 60 passengers and 482 kg of baggage on board. At 14:30 LT, aircraft HB-IXU with flight number LX 1105, was pushed back and the engines were started.

After the four engines had been started, the after engine start checklist had to be interrupted already during the first checklist item, because the crew had to carry out final manipulation in accordance with the MEL procedure in order to use the electrical generator of the APU for the return flight.

In the meantime, the commander had realised that there was another aircraft ready to taxi behind HB-IXU. According to his statement, the crew allowed themselves to be put under time pressure as a result of this. Subsequently, after resuming the after engine start checklist, they omitted to switch on both packs of the air-conditioning and cabin pressurisation system (Annex 1).

Among other things, the aircraft was configured as follows:

- Generator 1 OFF/RESET
- Generator 2 ON
- Engine Air 1,2,3,4 ON
- Engine Anti-Ice 1,2,3,4 OFF
- APU RUNNING
- APU Generator ON
- APU Air OFF
- Packs 1,2 OFF

At 14:42 LT, HB-IXU took off from runway 26L in Munich. When the flaps had been fully retracted, the PF asked the PNF to carry out the after take-off items. When he did so, the PNF did not notice the incorrect switch position of the air-conditioning and cabin pressurisation system. The PF also did not notice the incorrect switch position. When the aircraft had reached FL 100 and was being accelerated for the cruise climb, the PF requested the so called system check. During this check, among other things the PNF must check whether the air supply is switched correctly and whether the cabin differential pressure is rising. During this phase too, the crew did not notice anything unusual and the incorrect setting of the air-conditioning and cabin pressurisation system remained unnoticed.

Meanwhile, the cabin crew began to serve meals. At approximately 14:55 LT, the oxygen masks were suddenly deployed in the passenger cabin. This process is triggered automatically when the cabin altitude rises above 13 250 ± 250 ft. The *maître de cabine* (MC) ordered his colleague to sit down immediately on a passenger seat and put on an oxygen mask, which he did. The MC secured the service trolley and went to the forward flight attendant seat, which was only two rows away from his position. He also donned an oxygen mask.

The operator's procedures specify that flight attendants secure themselves in the nearest seat and put on an oxygen mask, in order to be prepared for an emergency descent.

Since the MC was sitting on his flight attendant seat, he was able to contact the commander using the intercom system. He asked whether there had been a decompression. The commander replied in the negative in surprise. The MC also explained that the cabin was secured and that all cabin occupants were wearing their oxygen masks. At this time, the aircraft was approximately 20 km north of Kempten at FL 200.

According to his information, the commander thought he had read off a cabin altitude of approximately 10 000 ft at this time. The flight crew were astonished that the warning had failed; it should have been triggered at a cabin altitude of 9300 ± 300 ft. This warning consists of two red flashing lights (attention getters), a red CABIN HI ALT annunciator (Annex 2) and a repetitive triple chime (audible warning).

The crew finally also donned their oxygen masks. The commander declared an emergency. The crew then initiated an emergency descent to FL 150, shortly afterwards to FL 120 and finally to FL 80. During this process the crew realised that the two switches of the air-conditioning and cabin pressurisation system (pack 1 and pack 2) were in the OFF position. After they had switched them on, the cabin pressure normalised and the pilots took off their oxygen masks. In this flight phase, the PF also took over communication with the responsible air traffic control unit.

The commander discussed the matter with the MC and thereafter informed the passengers, who then were taken care of by the flight attendants. Finally the cabin crew prepared the passengers for landing and also stowed the suspended masks in the baggage storage areas. As they did so, passengers informed them of an unusual smell. The crew informed the passengers that this smell originated from the hot oxygen generators in the panels above the passenger seats.

Flight LX 1105 landed at 15:17 LT on runway 14 in Zurich. The passengers disembarked the aircraft via the onboard stair.

1.2 Injuries to persons

Sixty passengers and four crew members were on board flight LX 1105.

There were no injuries to persons.

1.3 Damage to aircraft

The aircraft was not damaged.

1.4 Other damage

There was no damage to third parties.

1.5 Personnel information

1.5.1 Commander

Person	Swiss citizen, born 1971
Licence	Airline Transport Pilot Licence ATPL (A) according to Joint Aviation Requirements (JAR), first issued by the FOCA on 07.01.1999, valid till 02.10.2011

Ratings	Type rating AVRO RJ/BAe 146 as pilot in command Type rating SAAB 2000 as pilot in command Radiotelephony International (RTI) (VFR/IFR) Night flying NIT
Instrument flying rating	Instrument flight aircraft IR(A) Cat III AVRO RJ/BAe 146 instrument approaches, last extended on 25 September 2006, valid till 25.09.2007
Last proficiency check	Skill test as part of conversion to AVRO RJ/BAe 146 on 25 September 2006
Medical certificate	Class 1, no restrictions dated 18.04.2006, valid till 12.05.2007
Last medical examination	18.04.2006
Commencement of pilot training	1994

1.5.1.1 Flying experience

Total	4333:36 hours
as commander	2264:24 hours
on the type involved in the incident	143:36 hours
during the last 90 days	143:36 hours
of which on the type involved in the incident	143:36 hours
during the last 24 hours	4:24 hours
of which on the type involved in the incident	4:24 hours

1.5.1.2 Training of the commander on AVRO 146-RJ

The commander previously flew the SAAB 2000 in this function. He began conversion to the AVRO 146-RJ in August 2006. This conversion consisted of 11 lessons in the simulator. After flying training, which was concluded on 28 September 2006, the commander began route familiarisation.

On 19 October 2006 the commander passed the route check and successfully concluded route familiarisation after 44 flights and 50:36 hours experience on the aircraft type.

1.5.1.3 Duty times

On the previous day the commander involved in the serious incident represented the operator at a meeting of the European Regional Airline Association (ERA) in Brussels.

According to the commander, he felt rested when he started his duty.

	Duty on the previous day	on 11.12.2006, meeting in Brussels
	Flight duty time at the time of the serious incident	8:30 hours

1.5.2 Copilot

Person	Swiss citizen, born 1975
Licence	Airline Transport Pilot Licence ATPL (A) according to joint aviation requirements (JAR), first issued by the FOCA on 23.10.2003, valid till 31.05.2011
Ratings	Type rating AVRO RJ/BAe 146 as copilot Type rating EMB 135/145 as copilot Radiotelephony International RTI (VFR/IFR) Night flying NIT
Instrument flying rating	Instrument flight aircraft IR(A) Cat III AVRO RJ/BAe 146 instrument approaches, last extended on 27 May 2006, valid till 27.05.2007 Cat III EMB 135/145 instrument approaches, last extended on 19 September 2005, valid till 12.12.2006
Last proficiency check	Skill test as part of conversion on 27 May 2006
Medical certificate	Class 1, restrictions: VDL; must wear spectacles dated 01.09.2006, valid till 18.09.2007
Last medical examination	01.09.2006
Commencement of pilot training	1994

1.5.2.1 Flying experience

Total	4932:00 hours
as copilot	4525:42 hours
on the type involved in the incident	426:12 hours
during the last 90 days	164:36 hours
of which on the type involved in the incident	164:36 hours
during the last 24 hours	4:24 hours
of which on the type involved in the incident	4:24 hours

1.5.2.2 Training of the copilot on AVRO 146-RJ

The copilot previously flew the Embraer 145 in this function. He began conversion to the AVRO 146-RJ in April 2006. This conversion consisted of 11 lessons in the simulator. After flying training, which was concluded on 29 May 2006, the copilot began route familiarisation.

On 23 June 2006 the copilot passed the route check and successfully concluded route familiarisation with 51:48 hours experience on the aircraft type.

1.5.2.3 Duty times

Duty on the previous day	on 11.12.2006, off duty
Rest time	30:25 hours
Flight duty time at the time of the serious incident	8:30 hours

1.5.3 Maître de Cabine

Person	Swiss citizen, born 1960
Ratings	CT AVRO rating as *maître de cabine* - MC dated 08.11.2006 A340 rating as flight attendant dated 17.12.2003
Last proficiency check	Emergency and safety equipment training (ESET) on 08.08.2006
Flight attendant since	1982

1.5.3.1 Duty times

Start of duty on the previous day	on 11.12.2006, at 06:12 LT
End of duty on the previous day	on 11.12.2006, at 16:44 LT
Flight duty time on 11.12.2006	10:32 hours
Rest time	13:41 hours
Flight duty time at the time of the serious incident	8:30 hours

1.6 Aircraft information

1.6.1 General

Registration	HB-IXU
Type	AVRO 146-RJ100
Characteristics	Four-engine commercial jet aircraft
Manufacturer	British Aerospace Ltd., Woodford, Cheshire, England
Year of construction	1995
Serial number	E3276
Owner	Swiss International Air Lines Ltd., CH-4002 Basle

Operator	Swiss European Air Lines AG, CH-4052 Basle
Engines	4 Allied Signal LF507-1F jet engines
Auxiliary power unit	Sundstrand 4501690A
Operating hours, airframe	26 063 hours since manufacture
Operating cycles	22 816 since manufacture
Max. take-off mass	46 000 kg
Mass and centre of gravity	The aircraft's mass at the time of the serious incident was 35 500 kg. The mass and centre of gravity were within the permitted limits.
Fuel grade	Kerosene JET A1
Fuel quantities	According to the flight plan, take-off fuel was 4500 kg. Among other things, this included trip fuel of 1500 kg. The remaining 3000 kg would have allowed the aircraft to fly to an alternate aerodrome plus 55 minutes holding, without having to use the final reserve of 900 kg.
Registration certificate	No. 5, issued by the FOCA on 1 November 2005, valid till removal from the aircraft register
Airworthiness certificate	No. 2, issued by the FOCA on 1 November 2005, valid until revoked.
Certification	Scheduled line flights with passengers and cargo within coordinates 30° W to 60° E and 0° N to 80° N IFR Category IIIA (RVR 150 m / DH 50 ft) LVTO (RVR 125 m) RVSM B-RNAV (RNP 5)

1.6.2 Maintenance

The last scheduled A/B check took place on 2 December 2006. The operating hours and number of flying cycles were 25 997 hours and 22 756 cycles respectively.

The performance of maintenance work for continuous operation was noted accordingly in the technical documentation.

1.6.3 Technical limitations

The following relevant technical limitation was entered in the DDL:

Generator #1 inoperative

The aircraft was able to continue opearation in accordance with the minimum equipment list (MEL).

1.6.4 Pneumatic system

The pneumatic system is required for the two air-conditioning and cabin pressurization systems (pack 1 and pack 2) as well as for de-icing and anti-icing of the engine inlets and wings, to generate pressure in the hydraulic tanks and the water tank, and for toilet flushing. The air is bled from the engines or the APU and fed to the consumers via a piping system.

The two left engines 1 and 2 supply air to pack 1 and engines 3 and 4 to pack 2. The APU supplies both packs simultaneously via a load regulating valve. If the APU is overloaded when supplying air and electricity, electricity generation takes priority.

1.6.5 Air-conditioning and cabin pressurisation system

The air-conditioning and cabin pressurisation system regulates the air supply to the pressurised cabin, in order to keep it within a comfortable pressure and temperature range for the occupants. Two packs are installed.

Pack 1 supplies the cockpit and supports the passenger cabin. Pack 2 supplies the passenger cabin. If one pack or pneumatic feed fails, cabin pressure and temperature can still be maintained.

The steering of the pressure regulation system, which works analogously in HB-IXU, can be operated automatically or manually. On the copilot's instrument panel there is a three-function instrument which indicates the cabin altitude, the pressure difference between the cabin and the outside air and the rate of change of cabin altitude (Annex 2).

If the AUTO mode is selected by the corresponding push button the pressure selector/controller on the overhead panel automatically regulates the cabin pressure and the rate of pressure change via the outlet valves. The green AUTO annunciator lights up to confirm this mode of operation.

A warning comes up when the cabin altitude rises above 9300 ft ± 300 ft. This warning consists of two red flashing lights (attention getters), a red CABIN HI ALT warning annunciator and a repetitive triple chime audible warning. The warning is triggered by a cabin altitude warning switch.

1.6.5.1 Cabin altitude warning switch in aircraft HB-IXU

The cabin altitude warning switch (Annex 3) consists of a pressure sensor (1) with contact (2), a spring-tensioned contact pin (3 and 4) and an amplifier which operates a relay. This switch is located in a pressure-tight housing which has a pressure connection with a dust filter.

The pressure sensor is compressed as a function of the cabin pressure. If the cabin pressure reduces, the sensor extends towards the contact pin. The distance between the sensor and the contact pin is adjusted by means of a screw (5). The distance therefore corresponds to the set altitude of 9300 ft ± 300 ft. As soon as the sensor and contact pin come into contact, the CABIN HI ALT warning is triggered via an electrical circuit.

The cabin altitude warning switch installed in aircraft HB-IXU was secured immediately after the serious incident:

Year of construction	1994
Spare part number	10063

Serial number	F019
Operating hours since new	26 063 hours
Operating cycles since new	22 816
Operating hours since last check	13 888 hours
Operating cycles since last check	12 281
Last check in the aircraft	4 October 2001
Modifications	none
Set altitude	9300 ft

The maintenance programme of the MRB (maintenance review board) specifies that this switch must be checked after 15 000 cycles.

The maintenance department checked these switches during a C-check after every approximately 12 000 cycles. The last check took place on 4 October 2001. It had been envisaged to check this switch during the scheduled C-check on 30 May 2007.

1.6.6 Oxygen system

1.6.6.1 Oxygen system for cockpit crew

The oxygen system for the cockpit crew consists essentially of an oxygen cylinder, supply lines and three full-face quick-donning masks.

The oxygen cylinder can be filled via a valve. A pressure gauge is situated next to the filling valve. An overpressure valve is actuated in the event of overpressure in the oxygen cylinder.

The oxygen supply to the oxygen masks is regulated to 70 psi by a pressure regulator. A safety valve limits the pressure to max. 100 psi. In the console next to the copilot there is a main tap and a pressure gauge to check the pressure and therefore the quantity of oxygen in the oxygen cylinder.

1.6.6.2 Oxygen system for passengers and cabin crew

If pressure reduces, among other things the oxygen masks above the passenger and flight attendant seats deploy. The oxygen masks deploy automatically, triggered by an aneroid switch at a cabin altitude of 13 250 ft ± 250 ft.

The panel doors above the passenger and flight attendants' seats open and the oxygen masks drop down. If the automatic system fails, deployment of the masks can be actuated manually from the cockpit. To do this, one DROP OUT OVRD annunciator switch is installed in each of the two side consoles; these allow the automatic system to be overridden. The DROP OUT OVRD annunciator switch lights up when the ejector mechanism is triggered automatically or manually.

The oxygen is generated by chemical oxygen generators. As soon as a passenger pulls an oxygen mask towards him, the oxygen generator is activated by means of a pull cord. One oxygen generator supplies three oxygen masks for at least 22 minutes.

A test function allows the ejector mechanism to be checked periodically. When this is used, the panel doors open only approximately 3 cm and the oxygen masks do not deploy.

For first-aid purposes, four portable oxygen bottles with masks are on board.

1.6.7 Electrical system

The power supply consists of an AC and a DC system. The AC system is primarily supplied from two 40 kVA engine driven generators. If the generator of one engine fails, the remaining one automatically supplies the entire system.

The APU is used to generate electrical power on the ground when the engines are shut down as an alternative to an external power source. It is also used to compensate for the failure of an engine driven generator.

1.6.8 Cockpit door

The door that separates the cabin from the cockpit can be opened from both sides when it is not locked. However, it can be locked and unlocked mechanically or electrically only from the cockpit. The condition – locked or unlocked – is indicated by a green or red indicator near the closure lever. This door lock cannot be operated from the cabin side.

1.7 Meteorological information

1.7.1 General

The information in sections 1.7.2, 1.7.3 and 1.18.4.3 was provided by MeteoSwiss.

1.7.2 General weather situation

Switzerland was within the area of a high-pressure bridge expanding from Spain to Russia. During the day, a frontal zone passed the north side of the alps.

1.7.3 Weather at the time of the serious incident

Cloud	*3/8 SC basis 4300 ft AMSL* *3/8 SC basis 6100 ft AMSL*
Wind	*FL 50 230°/15 kt, Temperature 2 °C* *FL 100 270°/20 kt, Temperature -7 °C* *FL 180 290°/30 kt, Temperature -19 °C* *FL 240 260°/45 kt, Temperature -30 °C*

1.7.4 Aerodrome weather forecast

At the time of the serious incident, the following terminal aerodrome forecast (TAF) applied:

Quote from MeteoSwiss:

"LSZH 120900Z 121019 22005KT 9999 BKN040 T05/12Z T05/15Z="

In clear text, this means: On 12 December 2006 the following weather conditions were forecast for Zurich airport between 10:00 UTC and 19:00 UTC:

Wind	from 220° degrees at 5 kt
Meteorological visibility	above 10 km
Cloud	5-7/8 at 4000 ft AAL
Temperature forecast	At 12:00 UTC and at 15:00 UTC, a temperature of 5 °C is expected.

1.7.5 Aerodrome weather reports

Within the time span in which the flight involving the serious incident took place, the following aerodrome weather conditions (METAR) applied:

Quote from MeteoSwiss:

"EDDM 121320Z 25011KT 9999 FEW015 SCT023 BKN120 05/02 Q1025 NOSIG="

In clear text, this means:

On 12 December 2006, shortly before the 13:20 UTC issue time of the aerodrome weather report, the following weather conditions were observed at Munich airport:

Wind	from 250° at 11 kt
Meteorological visibility	above 10 km
Cloud	1-2/8 at 1500 ft AAL 3-4/8 at 2300 ft AAL 5-7/8 at 12 000 ft AAL
Temperature	5 °C
Dew point	2 °C
Atmospheric pressure	1025 hPa, pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere
Landing forecast	No significant change during the next two hours

Quote from MeteoSwiss:

"LSZH 121350Z 19004KT 150V240 9999 BKN045 07/M00 Q1026 NOSIG="

On 12 December 2006, shortly before the 13:50 UTC issue time of the aerodrome weather report, the following weather conditions were observed at Zurich airport:

Wind	from 190° at 4 kt, variable between 150° and 240°
Meteorological visibility	above 10 km
Cloud	5-7/8 at 4500 ft AAL
Temperature	7 °C
Dew point	between -0.5 °C and -0.1 °C
Atmospheric pressure	1026 hPa, pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere
Landing forecast	No significant change during the next two hours

1.8 Aids to navigation

Not applicable.

1.9 Communications

Radio communication between the crew and the respective air traffic control units of German and Swiss air navigation services took place normally and without any difficulties.

According to the crew's statements, support in connection with the emergency descent which they executed was helpful. The corresponding air traffic controllers only asked brief questions and complied with the crew's wishes.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

1.11.1 Flight data recorder

The flight data recorder was removed after the aircraft landed and the data were read out.

The parameter for the CABIN HI ALT warning indication is recorded as a status. No status change could be found on the DFDR.

The cabin altitude is not recorded on the DFDR.

1.11.2 Cockpit voice recorder

There are no recordings of cockpit conversations during the serious incident, because the power supply to the cockpit voice recorder (CVR) was not interrupted after the flight and therefore the conversation was overwritten.

1.11.3 Engine life computer

The engine life computer (ELC) is a recording device which is used primarily in connection with engine maintenance. Among other things, the ELC also records the valve position of the packs. Analysis of the ELC showed that both packs were switched off at the time of the serious incident.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

There are no indications of any health problems of the crew during the flight involved in the serious incident.

According to the crew's statements, they did not notice any signs of hypoxia during the flight.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Test and research

The cabin altitude warning switch described in section 1.6.5.1 was examined in the test installation of a maintenance department. The switch, which nominally is set to an altitude of 9300 ft, did not function up to an altitude of 25 000 ft.

This switch was then returned to the manufacturer for further investigation. This investigation showed that contamination and traces of heat on the contact were preventing it from functioning correctly.

The operator involved in this serious incident conducted a check on the altitude warning switches on all AVRO 146-RJ aircraft. One other defective switch was found.

The airline has been operating this aircraft type since 1990. Until the serious incident on 12 December 2006, no cabin altitude warning switch had ever had to be replaced because of a defect.

1.17 Organizational and management information

1.17.1 Swiss European Air Lines

1.17.1.1 General

Swiss International Air Lines was founded in March 2002 as a result of the insolvency of the then national airline Swissair in October 2001.

The initial basis for Swiss in company law was the regional airline Crossair in Basle, whose structures were used, with significant financial support from the Swiss Confederation, some cantons and Swiss economies to establish a new Swiss international airline. Crossair changed its name to Swiss International Airlines and took over 26 long- and 26 short-haul aircraft from the former Swissair along with a large proportion of their routes.

In October 2005, the management of Swiss announced that the regional fleet would be split off to a new company, Swiss European Air Lines AG. This fully-owned subsidiary of Swiss obtained its operating licence for the winter 2005 timetable and was able to start operation on 1 November 2005. The new company was conceived purely as an operating company and included exclusively the pilots and the aircraft fleet of the former Crossair airline.

After all remaining Saab 2000 aircraft had been phased out in autumn 2005, i.e. before the founding and split-off into Swiss European, by the 2006 summer timetable all Embraer EMB 145 aircraft had also been phased out and the fleet was standardised on the AVRO RJ85/100. From January to April 2006, an additional six used RJ100 aircraft were acquired and brought into service.

1.17.1.2 The operator

In the founding phase of Swiss International Air Lines, the intention was to merge the pilots of the former Swissair and Crossair. To support this process, the training and flight crew divisions, as well as flight safety, were merged in April 2002, before the formal commencement of operations. These areas were to perform a bridging function allowing the different corporate cultures to be combined.

Since no common work agreement of employment was produced initially, the two corps remained independent and were managed by a single management body. This situation continued until Swiss European Air Lines was founded, as all attempts to achieve a common contract of employment continued to founder.

The 'bridging' functions of air safety and training, however, remained combined, even through the split-off of the regional fleet.

1.17.1.3 Type rating

The parent company Swiss International Air Lines is the holder of a JAA licence as a type rating training organisation (TRTO) and conducts training courses on its aircraft types on its own behalf. Some parts of the training are delegated to the independent company Swiss Aviation Training SAT, which for its part is licensed as a flight training organisation (FTO).

For the practical training, the flying instructors, simulators instructors and procedure instructors from the respective fleet are made available to SAT.

The phase out of the Saab 2000 and the EMB 145 fleet as well as a distinct cut-back on pilots caused major personnel fluctuation. Within a short time period, very many pilots had to be converted to the AVRO 146-RJ and the average experience time on the aircraft type dropped.

1.17.2 Maintenance department

The department responsible for technical maintenance is based in Basle and was taken over as a complete unit from the former Crossair company. The maintenance department, certificated according to EASA (European Air Safety Agency) Part 145, is responsible for the aircraft types of the former Crossair company.

The maintenance operations for the AVRO fleet are basically split between two sites. A line-maintenance station is located in Zurich. The maintenance control center (MCC), troubleshooting, engineering, base maintenance and another line maintenance station are located in Basle.

1.18 Additional information

1.18.1 Operator's procedures

1.18.1.1 General

According to JAR-OPS 1.200 an air operator has to provide an operations manual (OM) for use by aviation personnel and for their instruction. The general rules for the OM are laid down in JAR-OPS 1[1] subpart P in article 1.1040. The structure and content is explained in greater detail in article 1.1045 and its annexes.

The OM consists of the following four volumes:

OM A	General/Basic
OM B	Aeroplane Operating Matters
OM C	Route and Aerodrome Instructions and Information
OM D	Training

Among other things, the normal procedures and duties of the crew, the corresponding checklists, the system for applying the checklists and the procedures necessary for coordination between flight crew and cabin crew must be listed in the OM B.

[1] Amendment 7

Planned additions or amendments to the operations manual must be submitted to the authority and if necessary approved.

The manufacturer of AVRO 146-RJ aircraft provides a manufacturer's operations manual (MOM). This publication is arranged in a different way from that required by JAR-OPS 1 for an OM B. However, the content is suitable for the production of an OM B by the air operator.

1.18.1.2 Swiss European Air Lines OM B

In 2004, an internal company working group undertook the revision of the OM B for the AVRO 146-RJ. After fourteen years of operation of the aircraft type with a corresponding large number of minor adaptations and after the transition to JAR-OPS 1, a new version of this OM B was needed.

The OM B should meet the content-related requirements of JAR-OPS 1.1045 but should also be user-friendly and easy to use. While working on the new OM B, the idea developed of adapting the standard operating procedures (SOP) to those of the other Swiss International Air Lines aircraft types. The key area of this adaptation was the decision to replace written checklists in flight by working with specified workflows and system checks.

Sections of the revised OM B were submitted to the manufacturer. The OM B as a whole was approved by the supervisory authority and introduced in November 2005 after a three-day introductory course for all pilots.

1.18.1.3 AVRO 146-RJ operating procedures and checklists

1.18.1.3.1 General

The first project for a four-engine short-haul jet aircraft designated HS 146 was launched by the Hawker Siddeley company in 1973. In 1978, the state-owned British Aerospace company took up the project again after it had been put on hold. The first flight of the BAe 146-100 took place in September 1981. As the first four-engine aircraft, it was designed for operation with a two-man crew.

In order to keep the crew workload within manageable proportions, the concept of the "dark cockpit" was applied. In normal operation, no annunciator lights should be illuminated. Amber or red annunciator lights inform the crew of faults. Normally, these annunciations are placed in the close vicinity of the corresponding switches.

In contrast with modern monitoring systems, the logic is limited to compare the desired state, selected by the respective switch, with its actual operating state. The jargon speaks of so called "not in position selected" (NIPS) messages. It is up to the pilots to monitor whether the selected operating state corresponds to the state which is desired for the respective phase of the flight. For example, if a pack of the air-conditioning and cabin pressurisation system is switched on without the corresponding valve then opening fully, the pilots will be made aware of this malfunction visually and acoustically. If the packs necessary for pressurisation are not switched on at all in flight, no automatic message is provided. The only warning which makes the crew aware of this condition is the cabin high altitude warning.

1.18.1.3.2 Checklists for the pneumatic system

The manufacturer's checklists and those of Swiss relating to the pneumatic system are shown below for comparison. The comparison is limited to the section after engine start-up and those during a climb.

After engine start[2]

Manufacturer	*Manufacturer's Operations Manual 9.30.1 05 Oct 98*
APU/ENG AIR	***AS REQUIRED***
PACKS	***ON***
DISCH VALVES	*CHECK/OPEN*
PACK 1	*ON, check APU EGT stabilized*
PACK 2	*ON, check APU EGT stabilized*

Swiss (earlier version)	*Pilots Information Handbook AVRO RJ B-2-0-27 21 May 2004*
ENG AIR, PACKS, AIR CONDITIONING	***AS REQUIRED/ON/SET***
ENG AIR switches (4)	*select ON*
Discharge valve position indicators	*check open*
PACK 1 switch	*select on*
PACK 2 switch	*select on*
FLT DECK TEMP CTRL switch	*confirm AUTO*
CABIN TEMP CTRL switch	*confirm AUTO*
AUTO rotary switches	*set to approx. mid position*

Swiss (current version)	RH1H/85 OM B 1.02.25 31 Mar 06
Air Supply/Packs/APU	***AS REQUIRED***
Set ANIMAL BAY heater switch as required	
Set and check bleed setting according supplementary information[3]	
Check flight deck TEMP CTRL switch set to AUTO	
Check CABIN TEMP CTRL switch set to AUTO	
Check AUTO rotary switches set to mid position	
Check CABIN AIR switch set to RECIRC or FRESH as required	
If APU not required: press APU overspeed test button to shut down the APU and wait 1 minute then set APU START/STOP switch to stop.	

[2] In bold type: text of the working checklist, additional text: expanded checklist.

[3] Supplementary Information, Air Conditioning, Use of APU AIR, OM B 1.02.40, see Annex 4.

In climb

Manufacturer	*Manufacturer's Operations Manual* *9.30.1 19 May 99*
ENG AIR	***ON***
APU AIR	***OFF***
APU VLV NOT SHUT & APU NRV LEAK annunciators	***Out***
Swiss (earlier version)	*Pilots Information Handbook AVRO RJ* *B-2-0-35 28 May 2003*
ENG AIR / PACKS / APU	***ON/STOP*** *Check/Switch ENG AIR 1,2,3,4 ON*
Airconditioning/Pressurization	*Check pack 1/2 to be on* *Set Air to "FRESH" or "RECIRC" as desired* *Check cabin pressure to increase.* *Check cabin rate of climb to be in normal range.* *Switch APU AIR OFF and check "APU valve not shut" and "APU NRV leak" annunciators to be out.* *Set APU start/stop switch to stop.* *Watch RPM and EGT to decrease normally.*
Swiss (current version)	RH1H/85 OM B 1.02.30 01.Nov.05
PF orders "AFTER TAKEOFF ITEMS"	*PNF adjusts bleed air setting for climb as outlined in supplementary information[2], stops APU if not further required, resets N_1 bugs and reports "AFTER TAKEOFF ITEMS COMPLETED"*
Passing FL100 during climb or after level off when cruising below FL100 or when reaching missed approach altitude after a go-around the PF orders *"SYSTEM CHECK"*	*The PNF shall check panels and pedestals according workflow pattern of system check and perform all required actions. He shall:* *a. Check that the after takeoff items have been performed (air change over)* *b. Stop the APU if not already stopped (or leave APU running for specific technical reasons acc. MEL).* *c. Check Flaps indicating 0° on flaps position indicator.* *d. Check gear lever in UP position and all gear lights out.* *e. Check required climb thrust is set.*

f. Check cabin pressurization instrument indicates increasing differential pressure and cabin pressurization ROC (rate of climb) not greater than 600 ft/min.

Upon completion PNF confirms "SYSTEM CHECK COMPLETED"

1.18.2 Database concerning incidents in flight operations

Since the end of the 'nineties, a database has been maintained for operation of the aircraft type involved in the incident, in which all incidents during flying operations which have become known are recorded.

Within the period from 1 April 2002 up to the introduction of the new procedures described in section 1.18.1.2, no incident comparable with this investigation was found in this database.

1.18.3 Cabin crew regulations

The relevant procedures for cabin crew are specified in the cabin safety procedure manual (CSPM). At the time of the serious incident, the following regulations, among others, applied in connection with a decompression:

Quote:

*"**14.6 Immediate actions required by cabin crew***

C/C must immediately take the nearest oxygen mask, secure themselves (if necessary on the lap of the passengers) and secure trolleys in the cabin.

The times of useful consciousness without breathing of additional oxygen are as follows:

FL 300 approx. 1 minute

FL 350 approx. 30 seconds

FL 400 approx. 15 seconds

14.7 Actions to be taken when the aeroplane is level

- *When the aeroplane has completed the emergency descent, the S/C checks on the commander's intention (call: S/C report to flightdeck), at the latest when oxygen flow ceases;*
- *C/C shall use working oxygen and take care of the passengers;*
- *if necessary, passengers must be re-seated away from damaged area;*
- *stow used oxygen masks*
  - *RJXX:*
    in hatracks;
- *stow away used portable oxygen bottles;*
- *do not stow masks back in generator box; and*
- *keep flight crew informed about situation in cabin and well being of passengers."*

1.18.4 Incident of HB-IXH on 3 January 2007

1.18.4.1 Preliminary remark

This incident was reported to the AAIB on 8 January 2007. In view of the similarity with the current investigation of the serious incident on aircraft HB-IXU on 12 December, the AAIB decided to incorporate the findings from this incident.

1.18.4.2 History of the flight

On the morning of 3 January 2007, an AVRO 146-RJ85 aircraft, registration HB-IXH, took off on a scheduled flight from Zurich (LSZH) to Hanover (EDDV) under flight number LX 814 at 07:47 LT from runway 28. On board were four crew members and 41 passengers.

Among other things, the aircraft was configured as follows:

- *Engine Air 1,2,3,4* *OFF*
- *Engine Anti-Ice 1,2,3,4* *OFF*
- *Wing Anti-Ice* *OFF*
- *Tail Anti-Ice* *OFF*
- *APU* *RUNNING*
- *APU Air* *ON*
- *Packs 1,2* *ON*

Throughout the entire flight the commander was pilot flying (PF) and the copilot was pilot not flying (PNF). The commander completed his training on this type in spring 2006, whilst the copilot had been flying this aircraft type since 2004.

The autopilot was not engaged in the first phase of the climb. Shortly before the aircraft reached a layer of cloud between 1200 and 2000 ft AGL the anti-ice system for engines 1,2,3,4 were switched on. Shortly afterwards, the crew received the Ice-Detect warning, upon which the anti-ice systems for the wings and tail were switched on. The APU air was not sufficient to deliver the necessary bleed air to all systems. Subsequently various NIPS messages lit up.

According to information from the crew, at this time the after take-off items had not yet been performed. After the crew had re-arranged the work distribution, the autopilot was engaged. In addition, the PF took over radio-communications.

The copilot searched for the cause of these NIPS messages and as a first step he performed the so-called air changeover. According to his statement, to do this he switched both packs off and thereby caused the NIPS displays for the valves of the packs to be extinguished. He also left the APU running. Among other things, the aircraft was then configured as follows:

- *Engine Air 1,2,3,4* *ON*
- *Engine Anti-Ice 1,2,3,4* *ON*
- *Wing Anti-Ice* *ON*
- *Tail Anti-Ice* *ON*
- *APU* *RUNNING*
- *APU Air* *OFF*
- *Packs 1,2* *OFF*

In principle, at this time the air system was correctly configured apart from the packs, which were switched off. Within the period until all valves concerned had reached their required position, various NIPS messages were still illuminated in the cockpit. In view of these indications, the copilot consulted the abnormal checklist (ACL).

In this phase, flight LX 814 climbed through FL 100, at which point the PF should have requested the system check described in section 1.1.4. During simulator training on this type, pilots were advised to fully complete the manipulations of an ACL before performing the system check.

After the copilot had completed the ACL and all the displays and warnings described above had disappeared and even before the system check had been ordered, the CABIN HIGH ALT warning occurred at FL 185. The commander requested permission from air traffic control to stop the climb at FL 190. The crew donned oxygen masks and carried out the remaining necessary manipulations.

Both pilots realised simultaneously that the cause of this problem was the packs of the air-conditioning and cabin pressurisation system, which were switched off. Once both packs had been switched on, air supply to the cabin normalized. According to the crew, the warning lasted for about two minutes.

Once the pressure indication system of the cabin showed normal values again, it was decided to continue the flight to Hanover (D).

1.18.4.3 Meteorological information

Weather/cloud	*NSW / 1-2/8 at 2000 ft AMSL,* *3-4/8 at 2600 ft AMSL, 7/8 at 3400 ft AMSL*
Visibility	*Above 10 km*
Wind	*Surface wind from 240° at 4-6 kt* *At FL180 wind from 360° at 50 kt.*
Temperature/dewpoint	*LSZH: 3 °C / 2 °C*
Atmospheric pressure	*LSZH 1033 hPa*
Position of the sun	*Sun still below the horizon.* *Azimuth 121°, elevation -3°*
Hazards	*Moderate icing above 2000 ft AMSL.* *Moderate turbulence below FL 180.*

1.19 Useful or effective investigation techniques

No new techniques applied.

2 Analysis

2.1 Technical aspects

2.1.1 General

The serious incident was not caused by a technical fault but by a manipulation which was omitted by the cockpit crew. However, a defective cabin altitude warning switch did prevent the cockpit crew from being warned when the cabin altitude exceeded the value of 9300 ft ± 300 ft.

2.1.2 Triple gauge for displaying cabin data

After the MC had contacted the commander via the intercom system and asked whether there had been a decompression in the cabin, the commander replied in the negative. He thought he had read off a cabin altitude of approximately 10 000 ft at this time.

This perception may possibly be explained by the type of the display and the lay-out of the instrument (Annex 2).

2.1.3 Cabin altitude warning switch

In the AVRO 146-RJ aircraft, only one cabin altitude warning switch is installed. This means that this warning system does not incorporate any redundancy. In view of the long interval between checks, any switch fault may remain undetected for a long period.

The Swiss AAIB is of the opinion that this situation is not adequate for monitoring a vital parameter.

2.1.4 Cockpit door

The system used on the aircraft type involved in the serious incident to secure the cockpit door cannot be unlocked from the cabin side. This means it is impossible for the cabin crew to enter the cockpit if the pilots are no longer able to unlock the door.

The Swiss AAIB is of the opinion that it is necessary to take measures which ensure that in an emergency the cabin crew can gain access to the cockpit.

2.2 Human and operational aspects

2.2.1 Flight crew

2.2.1.1 Cockpit crew of HB-IXU

The crew of HB-IXU previously flew on aircraft types which had a modern cockpit layout.

Both pilots had been flying on the AVRO 146-RJ for only a short time. They had been trained in accordance with the standard operating procedures (SOP) introduced in November 2005.

As described in section 1, the aircraft type involved in the serious incident belongs to a generation of aircraft which was on the one hand equipped with modern flying instruments but which corresponded to an aircraft of the older generation in terms of the operations of systems, such as the pneumatic system, for example. These do not yet have system displays on screens with corresponding switch layouts which makes it easier for the crew to switch systems correctly under both normal and abnormal conditions.

For this reason, systems operation on aircraft of the older generation increases crew workload. It takes longer for the pilot to acquire the routine necessary to handle more complex situations quickly and without error. Neither a checklist with many manipulations performed from memory nor a workflow procedure with no checklists provides the necessary support for swift and correct operation of onboard systems.

In the present case, the crew additionally had to deal with the unusual manipulations in connection with the defective electrical generator on engine number 1. In addition to these manipulations there was the self-imposed time pressure, which cumulatively led to the air-conditioning and cabin pressure packs not being switched on.

It must be assumed that the complexity of the pneumatic system and the crew's still limited experience of the aircraft type meant that it was not noticed during performing the after take-off items and the system check that the packs were not switched on.

Once the cockpit crew had been made aware by the *maître de cabine* of the fact that the oxygen masks had deployed, they reacted appropriately to the situation, immediately requested an emergency descent and rectified the incorrect switch positions. The subsequent decision to continue the flight to Zurich is understandable.

2.2.1.2 Cabin crew of HB-IXU

Since the *maître de cabine* had been working as a flight attendant since 1982, he can be described as very experienced.

When the oxygen masks suddenly deployed, the *maître de cabine* reacted without delay, secured the service trolley and made his way to his flight attendant's seat.

In the Swiss AAIB's opinion this procedure was correct in this case, since it was only from his station that he was able to inform the cockpit crew about what had happened.

2.2.1.3 Cockpit crew of HB-IXH

Analysis of the HB-IXH incident on 3 January 2007 permits the conclusion that the conditions described in section 2.2.1.1, which led to the miss manipulation basically also applies to this case.

2.2.2 Procedures

2.2.2.1 Procedures for cockpit crews

This case shows that the applied procedures of working without written checklists do not provide the crew with the necessary support in operating the complex pneumatic system swiftly and without error.

The Swiss AAIB is therefore of the opinion that checklist items or manipulations should be listed explicitly in the checklist. It is therefore indispensable also to work with written checklists in flight. When this aircraft was developed, it was never the intention to work in flight without written checklists, in contrast to aircraft of the newer generation where this work concept has already been taken into consideration in the development of aircraft systems.

2.2.2.2 Procedures for cabin crews

The existing procedures in connection with a decompression assume that the pilots realize the following, among other things:

- a decompression in the cabin
- cabin pressure is not increasing and as a result the oxygen masks in the passenger cabin deploy.

In these cases, the cabin crew expect information or instructions from the cockpit and prepare for a possible emergency descent.

In the procedures and in crew training, the case should be introduced in which the passenger oxygen masks are deployed and no information is provided from the cockpit and no emergency descent is initiated.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for air transport.
- The cabin altitude warning switch was defective and was unable to trigger the CABIN HI ALT warning.
- The cabin altitude warning switch was last checked on 4 October 2001.
- The next functional check on the cabin altitude warning switch was scheduled for 30 May 2007.
- The cabin altitude is not recorded on the DFDR.

3.1.2 Crew

- The crew were in possession of the necessary licences for the flight.
- There are no indications of any health problems of the crew during the flight involved in the serious incident.
- The commander completed his training on the AVRO 146-RJ on 19 October 2006.
- The copilot completed his training on the AVRO 146-RJ on 29 May 2006.

3.1.3 History of the flight

- Because of a defective electrical generator, flight LX 1105 of 12 December 2006 was dispatched in accordance with the minimum equipment list (MEL).
- After starting the engines, the crew of flight LX 1105 did not switch on the air-conditioning and cabin pressurisation system (packs 1 and 2).
- While performing the after take-off items and the system check, it was not noticed that the packs were not switched on.
- Because of a defective cabin altitude warning switch, the CABIN HI ALT warning was not triggered when the cabin altitude exceeded 9300 ft.
- When the cabin altitude reached 13 000 ft, the oxygen masks in the cabin were deployed.
- The *maître de cabine* secured the service trolley, made his way to his flight attendant's seat and informed the cockpit crew.
- The cockpit crew donned their oxygen masks and initiated an emergency descent.
- Once the cockpit crew had switched on the air-conditioning and cabin pressurisation system (packs 1 and 2), the cabin pressure normalised.
- Flight LX 1105 continued and landed on runway 14 at Zurich-Kloten airport.
- The meteorological conditions on this afternoon did not influence the serious incident.

3.1.4 General conditions

- The checklists relating to operation of the complex pneumatic systems of the AVRO 146-RJ are kept in summary form. Checklist items and/or manipulations are not explicitly listed in the checklist.
- In November 2005, the operating procedures on the AVRO 146-RJ were changed by the operator.
- During operation of the aircraft in the air, written checklists are no longer used.
- In the procedures for the crew there is no provision for the case which occurred on flight LX 1105 on 12 December 2006.

3.2 Causes

The serious incident is attributable to the fact that after starting the engines the crew did not switch on the air-conditioning and cabin pressurisation system and did not realise this during the climb.

The following factors contributed to the serious incident:

- a defective cabin altitude warning switch, which was unable to trigger the CABIN HI ALT warning.
- procedures and checklists which were not adapted to the complexity of the onboard pneumatic system.

4 Safety recommendations and measures taken since the serious incident

4.1 Measures taken since the serious incident

4.1.1 Maintenance interval of the cabin altitude warning switch

From 30 March 2007 onward, the operator's maintenance department reduced the inspection interval from 12 000 to 4000 cycles. This means that the function of the cabin altitude warning switch is checked during every C-check.

As a result of the recent incidents where the cabin altitude warning switch failed to operate when required a review was carried out by the manufacturer. The outcome of this review is to change the maintenance review board report - MRBR to have the first function check carried out at 15 000 cycles with repeat checks at 5000 cycle intervals. This change will be promulgated through the MRB process with presentation to the associated working group in March 2008.

4.2 Safety recommendations

4.2.1 Explicit mention of vital items in the working checklist

4.2.1.1 Safety deficit

During a scheduled flight from Munich to Zurich on an AVRO 146-RJ aircraft, the crew did not switch on the two packs of the air-conditioning and cabin pressurisation system after starting the engines.

After take-off, when the flaps had been fully retracted, the copilot as PF (pilot flying) ordered from the PNF (pilot not flying) to perform the after take-off items. While performing these, the PNF overlooked the incorrect switch position of the packs. Also the PF did not realise that the incorrect switch position.

After the aircraft reached 10 000 ft and accelerated for the cruise climb, the PF asked for the so-called system check. During this check, among other things, the PNF had to check whether the air supply was configured correctly and that cabin pressure was increasing. During this phase too, the crew did not notice anything unusual and the incorrect switch position of the packs remained unnoticed.

After take-off, as a result, the cabin altitude climbed above 10 000 ft.

Due to a defective cabin altitude warning switch that should have triggered the CABIN HI ALT warning at a cabin altitude of approximately 9300 ft, this warning was not activated.

The text in the checklist of the manufacturer asks explicitly for switching the packs on after engine start (manufacturers operation manual Vol. 2, chapter 9.30.1). In the working checklist part for the after take off- respectively climb items the packs are no longer mentioned. This does not take into account that, on this aircraft type, under certain circumstances, it might be necessary to leave the packs off for take-off. It is therefore compelling that after every take-off the switching on of the packs, increase of the differential pressure and the climb rate of the cabin altitude must be checked.

4.2.1.2 Initiated measures

The aircraft manufacturer has already undertaken a review of the checklist aspects of normal operation and decided to draft a checklist amendment to enhance the need to check pressurisation settings at 10 000 ft intervals and to also include a line item to ensure that the packs are selected on in the After Takeoff checks (Annex 5).

4.2.1.3 Safety recommendation No. 395

EASA (European Air Safety Agency) shall require that the amended checklist for the aircraft type BAe 146-AVRO RJ shall be introduced in the sense of the draft as soon as possible.

4.2.2 Use of written checklists in flight

4.2.2.1 Safety deficit

During a scheduled flight from Munich to Zurich on an AVRO 146-RJ aircraft, the crew did not switch on the two packs of the air-conditioning and cabin pressurisation system after starting the engines.

After take-off, when the flaps had been fully retracted, the copilot as PF (pilot flying) ordered from the PNF (pilot not flying) to perform the after take-off items. While performing these, the PNF overlooked the incorrect switch position of the packs. Also the PF did not realise that the incorrect switch position.

After the aircraft reached 10 000 ft and accelerated for the cruise climb, the PF asked for the so-called system check. During this check, among other things, the PNF had to check whether the air supply was configured correctly and that cabin pressure was increasing. During this phase too, the crew did not notice anything unusual and the incorrect switch position of the packs remained unnoticed.

Due to a defective cabin altitude warning switch that should have triggered the CABIN HI ALT warning at a cabin altitude of approximately 9300 ft, this warning was not activated.

The AVRO 146-RJ is used by the operator since the early nineties.

In November 2005, the operating procedures regarding checklists have been changed. Among other things, during operation of the aircraft a written checklist is now used only on the ground. From take-off to landing, the crew carries out routine manipulations without a checklist in accordance with defined work flows.

4.2.2.2 Safety recommendation No. 394 (previous No. 386)

The Federal Office for Civil Aviation shall ensure that in the case of AVRO 146-RJ aircraft the operator also works with written checklists in connection with routine manipulations when the aircraft is in flight.

4.2.3 Adaptation of the procedures for crews

4.2.3.1 Safety deficit

During a scheduled flight from Munich to Zurich on an AVRO 146-RJ aircraft, the crew did not switch on the two packs of the air-conditioning and cabin pressurisation system after starting the engines.

After take-off the cabin altitude climbed above 10 000 ft.

Meanwhile, the cabin crew began to serve meals. The oxygen masks were suddenly deployed. The *maître de cabine* (MC) ordered his colleague to sit down immediately on a passenger seat and put on an oxygen mask, as required by the internal procedures. The MC secured the service trolley and went to the forward flight attendant seat, which was only two rows away from his position. He also donned an oxygen mask.

The operator's procedures specify that flight attendants secure themselves in the nearest seat and don an oxygen mask, in anticipation of an emergency descent.

Since the MC was sitting on his flight attendant's seat, he was able to contact the commander using the intercom system. He asked whether there had been a decompression. The commander replied in the negative in surprise. The MC also confirmed that the cabin was secure and that all cabin occupants were wearing their oxygen masks.

At this time, according to the recordings of the DFDR (digital flight data recorder), the aircraft was approximately in the region between Munich and Kempten at FL 200.

According to his statement, the commander realised that the cabin altitude was approximately 10 000 ft. The flight crew were astonished that the CABIN ALT HI warning did not occur; it should have been triggered at a cabin altitude of 9300 ft.

The crew finally also donned their oxygen masks. The commander declared an emergency. The crew then initiated an emergency descent to FL 150, shortly afterwards to FL 120 and finally to FL 80. During this process the crew realised that the two switches of the air-conditioning and cabin pressurisation system (pack 1 and pack 2) were in the OFF position. After they had switched them on, the cabin pressure normalised and the pilots took off their oxygen masks.

Due to a defective cabin altitude warning switch that should have triggered the CABIN HI ALT warning at a cabin altitude of approximately 9300 ft, this warning was not activated.

4.2.3.2 Safety recommendation No. 396 (previous No. 388)

The FOCA shall ensure that in the procedures, in initial and recurrent training of the crews, the procedure for the case in which the oxygen masks deploy in the cabin without any information being received from the cockpit or an emergency descent being initiated, shall be subject of discussion.

4.3 Safety recommendations in the accident report 11/2006 concerning the accident of Helios Airways flight HCY522, dated 14 August 2005

In the above mentioned investigation report a total of 16 safety recommendations were expressed. The Swiss AAIB considers the following three safety recommendations as relevant in connection with the serious incident of HB-IXU, dated 12 December 2006:

"**2006 – 41** EASA/JAA require all airlines to amend cabin crew procedures, so that, when the oxygen masks deploy in the cabin due to loss of cabin pressure or insufficient cabin pressure and if the aircraft does not suspend climb, or level-off or start a descent,, the Cabin Chief (or the cabin crew member situated closest to the flight deck) be required to immediately notify the flight crew of the oxygen masks deployment and to confirm that the flight crew have donned their oxygen masks.

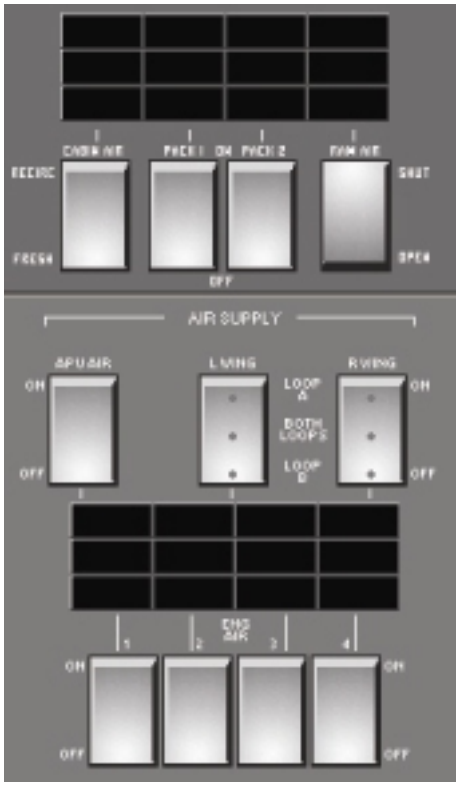
2006 – 42 EASA/JAA require aircraft manufacturers to install in newly manufactured aircraft, and on a retrofit basis in older aircraft, in addition to the existing cabin altitude warning horn, a visual and/or an oral alert warning when the cabin altitude exceeds 10 000 ft.

2006 – 47 EASA/JAA and ICAO require the aircraft manufacturers to also record cabin altitude on the FDR."

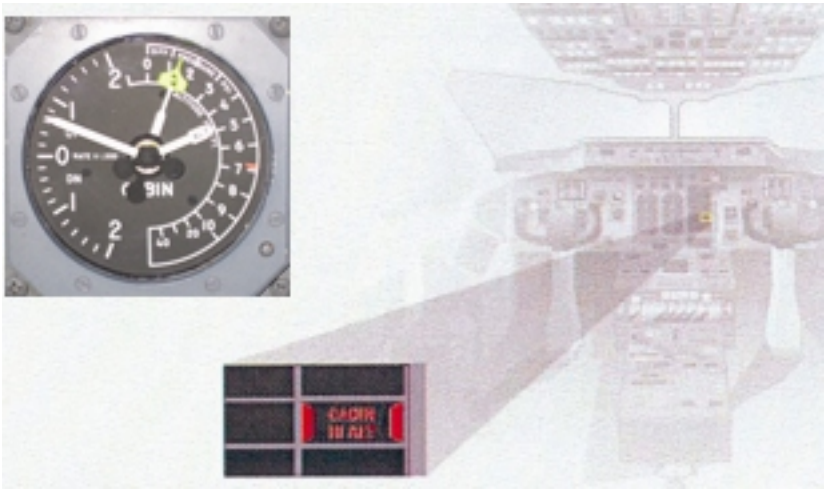
Berne, 26 March 2008 Aircraft Accident Investigation Bureau

Annexes

Annex 1: Switch panel for the AVRO 146-RJ pneumatic system



Annex 2: Triple instrument and warning annunciator CABIN HI ALT



Triple instrument for measuring cabin altitude, cabin differential pressure and rate of pressure change.

Annex 3: Cabin altitude warning switch

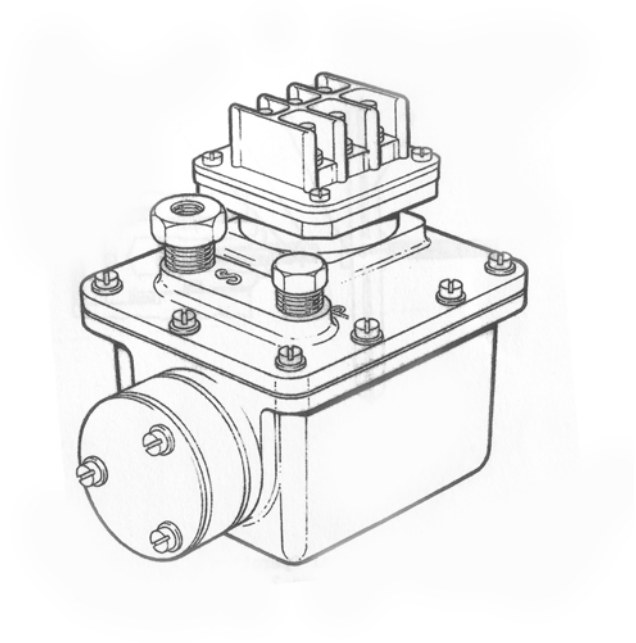


Fig. 1: External view of the cabin altitude warning switch

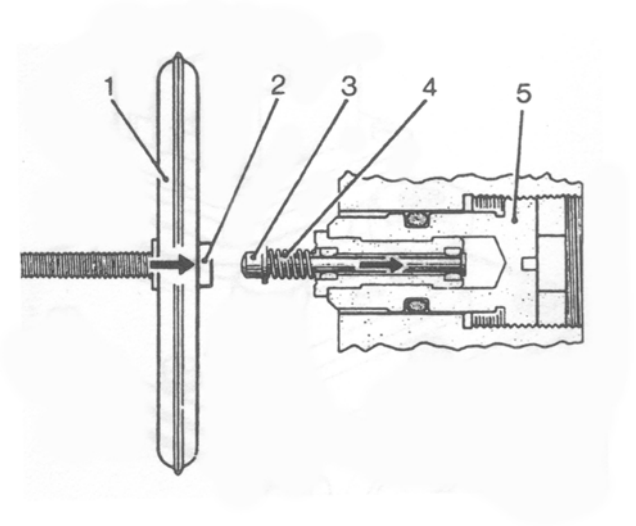


Fig. 2: Cross-section of the trigger mechanism

Annex 4: OM B 1.02.40 - AIR CONDITIONING

USE OF APU AIR

General

Use of aircraft APU is restricted at some airports; except in abnormal/emergency conditions, the crew must only operate the APU as allowed by local restrictions. The APU must not be started during refuelling or defuelling. The APU AIR switch should not be selected ON until the APU has been running for at least 1 minute.

Before the engines are started it is more economical to run one air conditioning pack than both, if satisfactory cabin conditioning can be obtained.

Before APU shutdown stop bleed air extraction (e.g. PACKs OFF or ENG AIR ON and APU AIR OFF). The use of APU air after airframe de-icing should be avoided due to contamination of the air conditioning system.

AIR AND BLEED SETTINGS FOR TAKE-OFF:

APU air ON , Engine Anti Ice ON or OFF

The standard air and bleed settings for take-off are:

- CABIN AIR RECIRC
- APU AIR ON
- ENG AIR 1, 2, 3 and 4 OFF
- PACK 1 and 2 ON

AFTER TAKE-OFF ITEMS

SOP item 13

- CABIN AIR check RECIRC
- ENG AIR 1, 2, 3 and 4 ON
- PACK 1 and 2 check ON
- APU AIR OFF

Note: With this setting, ENG ANT-ICE may be switched ON before selection of climb thrust. OUTER WING ANT-ICE, TAIL ANT-ICE and INNER WING DE-ICE must not be switched ON before selection climb thrust and bleed source changed to ENG AIR

Engine Anti Ice OFF, APU air OFF

If APU air is not available, engine anti-ice is not required and performance considerations allow, then the following alternative settings may be used (except for Take-off with Flaps 33):

- CABIN AIR RECIRC
- APU AIR OFF
- ENG AIR 1, 2, 3 and 4 ON
- PACK 1 and 2 ON

AFTER TAKE-OFF ITEMS

SOP item: Not required

Engine Anti Ice ON, APU air OFF

If APU air is not available and engine anti-ice is required for take-off or performance considerations prohibit the use of engine air, the following settings are used:

- CABIN AIR FRESH
- APU AIR OFF
- ENG AIR 4 (only) ON
- PACK 1 and 2 OFF

In this case, after selection of climb thrust PNF selects:

- ENG AIR 3 ON
- PACK 2 ON
- ENG AIR 2 and 1 ON
- PACK 1 ON
- CABIN AIR RECIRC

Annex 5: Extract of amended checklist draft for normal operation

AVRO 146-RJ FCOM Vol 3 Pt 2 Nov 22/07	NORMAL CHECKLIST CARD 2	Constructor Number - E3283Draft

BEFORE START	
SAFETY/EXT CHECKS	COMPLETE
	COVERS & PINS STOWED
BRIEFING	COMPLETE
BRAKES	YELLOW & PARK
	PRESS & TEMP CHKD
HYDRAULICS	ALL OFF
FUEL PANEL	CHKD/SET
PRESSURIZATION	SET
ICE DETECT	ON
LIGHTS & NOTICES	SET
AIR CONDITIONING	CHKD/SET
FASTEN BELTS	ON
FUEL	CHKD
FLIGHT ID	SET
ALTIMETERS	SET & X-CHKD
MWS GND OP	RESET
SHIP'S PAPERS	COMPLETE
TRP/N_1/SPEEDS	CHKD/BUGS SET
IRS	POSN RESET

STARTING	
FLIGHT DECK DOOR	LOCKED
MOBILE PHONES	OFF
APU GEN/EXT AC	SET
BEACON	ON
PACKS & APU AIR	OFF if starting from APU
ENG ANT-ICE	ON
AC PUMP	OFF
FUEL PUMPS	ON
START POWER	NORM
START MASTER	ON
START SELECT	ENG ...
ENGINE	START

AFTER START	
START POWER	NORM
START SEL & MSTR	OFF
ENG ANT-ICE	AS REQD
GENERATORS	ON
BRAKE FANS	AUTO
HYDRAULICS	ON & CHKD
HEATERS	ON
APU/ENG AIR	AS REQD
PACKS/CABIN AIR	AS REQD
DOORS & WINDOWS	CLOSED
CHOCKS & GRND EQUIP	REMOVED
TRANSPONDER	AS REQD

IMMEDIATE RETURN: For landing or short low level flights, only Descent and Approach checks marked ★ need to be completed. If Climb checks have been done, all Descent and Approach checks must be completed.

BEFORE TAKE-OFF	
BRAKES	YELLOW & GREEN
	CHKD, YELLOW
FLAPS	...° SELECTED & CHKD
FLT INSTRUMENTS	CHKD
FLIGHT DIRECTOR	AS REQD
TRIMS	... SET & CHKD
CONFIG	CHKD
SEATS & HARNESS	LOCKED & SECURE
NAV AIDS & TPNDR	SET AS CLEARED
BRIEFING	REVIEWED
SPEEDS/ N_1	CHKD
CONT IGN A & B	AS REQD
CABIN	SECURE
LINING UP	
RADAR	AS REQD
LIGHTS & STROBES	ON
A/T	AS REQD
CONTROLS	CHKD
MWS	CHKD

AFTER TAKE-OFF	
GEAR	UP & LIGHTS OUT
FLAPS	UP
TRP	CLIMB
ENG AIR	ON
APU AIR	OFF
PACKS	ON (Pressurizing)

CLIMB	
ALTIMETERS	AS REQD & X-CHKD
PTU	OFF
APU	STOP
FASTEN BELTS	AS REQD
LIGHTS	OFF

DESCENT	
PTU	ON
★ PRESSURIZATION	SET
★ BRIEFING	COMPLETE
★ LANDING DATA	CHKD, BUGS SET
SEATS & HARNESS	LOCKED, SECURE

APPROACH	
★ ALTIMETERS	QNH/QFE ... SET & X-CHKD
FASTEN BELTS	ON
APU	AS REQD
★ FUEL PANEL	SET
★ CABIN	WARNED
★ STEEP APPROACH	AS REQD

LANDING	
GEAR	DOWN 3 GREENS
BRAKES	YELLOW & CHKD
LIGHTS	AS REQD
FLAPS	SET FOR LANDING
CABIN	SECURE
AIRFRAME ANT & DE-ICE	OFF
APU AIR	AS REQD
ENG AIR & PACKS	AS REQD
NOSE-WHEEL STEERING	CENTRED AT 500 FT