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Swiss Transportation Safety Investigation Board STSB

Aviation Division

Final Report No. 2264 of the Swiss Transportation Safety Investigation Board STSB

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

operated by Swiss European Air Lines with the callsign SWR35R

on 24 March 2013

near waypoint LUSAR
50 NM north-west of Geneva airport

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Causes

L’incident grave est dû à une perte de contrôle de la pressurisation probablement causée par la présence de glace dans les conduites pneumatiques du système de contrôle des deux vannes de régulation d’échappement cabine ainsi qu’à un frottement excessif altérant le fonctionnement de la vanne de régulation d’échappement cabine secondaire.

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances and causes of the accident which is the subject of the investigation.

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

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

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

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

To ensure the protection of data, the report uses the generic masculine.

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

Table of Contents

Final report

Synopsis

Owner	Swiss International Air Lines Ltd., Postfach, 4002 Basel, Switzerland
Operator	Swiss European Air Lines AG, Malzgasse 15, 4052 Basel, Switzerland
Manufacturer	British Aerospace Regional Aircraft Ltd, United Kingdom
Aircraft type	AVRO 146-RJ100
Country of registration	Switzerland
Registration	HB-IYY
Flight number	LX0435
Callsign	SWR35R
Location	Near waypoint LUSAR, 50 NM north-west of Geneva airport
Date and time	24 March 2013 at 15:15 UTC

Investigation

The serious incident occurred at 15:15 UTC. It was notified to the Swiss Accident Investigation Board (SAIB) at 16:10, which opened an investigation the same day.

The SAIB[1] notified the serious incident to the United Kingdom authorities which appointed an accredited representative.

The final report is published by the Swiss Transportation Safety Investigation Board (STSB).

Summary

On 24 March 2013, an AVRO 146-RJ100 aircraft, registration HB-IYY, was making scheduled flight LX0435 from London-City to Geneva. Twenty-five minutes before landing the aircraft was maintaining flight level FL 270. It was in contact with the Geneva area control centre which cleared it to follow the arrival route from the north, LUSAR 1N. The flight crew perceived a change in cabin pressure. An error code was displayed on the cabin pressure controller, but no alert was activated. The cabin altitude and differential pressure were normal for this flight phase. The cabin vertical speed indicator indicated a rate of climb. The co-pilot informed the air traffic controller of a pressurisation problem and requested permission to descend.

The commander switched the cabin pressurisation system to manual mode. While the aircraft was descending, the passenger oxygen masks were deployed. The flight crew declared an emergency situation. The descent continued and the landing was uneventful. The passengers were able to disembark the aircraft normally and none required medical assistance.

[1] SAIB (Swiss Accident Investigation Board) become the STSB (Swiss Transportation Safety Investigation Board) on the 1. February 2015

Cause

The serious incident was due to a loss of control of the pressurisation system, which was probably caused by the presence of ice in the pneumatic pipes of the cabin regulation valve control system and excessive friction degrading operation of the secondary cabin regulation valve.

Safety recommendations

None

1 Factual information

1.1 History of the flight

1.1.1 General

The pre-flight history and history of the flight are based on recordings of radio communications, flight parameters, radar plots, the statements of flight crew members and information received from the maintenance company. The recording of conversations in the cockpit (cockpit voice recorder - CVR) was unusable because the power supply to the recorder was not switched off after landing.

During the flight, the co-pilot was the pilot flying (PF), the commander performed the function of pilot monitoring (PM). Following onset of the pressurisation problems, the commander managed the task sharing for abnormal situations, known as worksplit. The co-pilot remained at the controls and handled radiotelephony transmissions. The commander managed the checklist for abnormal situations, communication with the cabin crew and passenger announcements.

This was a scheduled commercial flight, performed under instrument flight rules (IFR).

1.1.2 Previous incidents

1.1.2.1 Incident of 8 March 2013

On 8 March 2013, when HB-IYY was at cruising level FL 300, an inadvertent drop out of the cabin oxygen masks occurred, despite normal pressurisation operation. The pressurisation and oxygen systems are described in section 1.6.

The following events were recorded:

- activation of cockpit warning “PAX OXY OUT”;
- tripping of cockpit circuit-breaker “PAX OXY”;
- failure of the automatic announcement for passengers;
- non-dropping of the oxygen masks in the forward toilet and front cabin crew working area;
- oxygen masks in seat rows 19 (seats AB), 14 (seats DEF) and 16 (seats DEF) were used.

Following this incident, the following work was carried out:

- reinstallation of non-dropped oxygen masks due to incorrect installation;
- replacement of used oxygen generators;
- checking of the mask drop out electrical system; this did not reveal any anomalies.

As a precautionary measure, the following main components of the drop out system were replaced:

- the two override switches located in the cockpit together with their connector;
- the masks drop out control relay and its electronic card controlling the two-second drop out delay;
- the aneroid capsule which triggers automatic drop out when the cabin altitude exceeds 13,250 ft.

A test of the triggering system was performed in accordance with the maintenance manual procedure. The system operated correctly and the aircraft was returned to service on 9 March 2013.

No pressurisation or oxygen mask drop out problem was reported between 9 and 24 March 2013.

1.1.2.2 First flight on 24 March 2013

On the morning of 24 March 2013, HB-IYY made its first flight, from Geneva to Nice, with the same flight crew as that on board the subsequent serious incident flight. The outside air temperature was 2°C during the night preceding departure and 5°C at the time of takeoff. When passing FL 109 during the climb to FL 230, a single chime alert sounded, momentarily accompanied by the main flashing amber attention getting lamps. The latter then went out without any action on the part of the flight crew. The pressurisation system then declared a minor fault by illuminating in white the "PRESSN" warning on the central warning panel (CWP). The flight crew applied the checklist for this abnormal situation, which required the error codes displayed by the cabin pressure controller (CPC) to be recorded. The commander reported the incident to the company after landing in Nice, where the outside temperature was 10°C.

The return flight to Geneva was uneventful. After landing in Geneva, the commander recorded the following in the aircraft technical log: "*On flight LX 520, GVA-NCE, FL 109: during climb MC present followed by a white PRESSN indication, MASTER CAUTION*[2] *went off again. On OVHD panel pressurisation D/P PRI visible. MCL performed by pressing CLEAR DISPLAY, FAULT D/P SEC indication. Pressing again until D/P 6.2 indicating. PRESSN white remained on. Controllable in AUTO MODE. Test successful. Return flight uneventful."* At Geneva, the maintenance service tested the CPC. The test was satisfactory and the aircraft left with the same crew for a flight to London-City.

1.1.3 Flight on which the serious incident occurred

On 24 March 2013 at 14:09 UTC, an AVRO 146-RJ100 aircraft registration HB-IYY took off from London-City airport. It was making the scheduled flight LX0435 to Geneva. This was the fourth flight of the day for the aircraft and crew. The co-pilot was at the controls. Twenty-five minutes before landing, the aircraft left its cruising level FL 310 and then maintained FL 270. The flight crew was in contact with the Geneva area control centre, which cleared them to follow the arrival route from the north, LUSAR 1N. The pilots perceived a change in the cabin pressure and checked the pressurisation system readings. The error code "PRI" was displayed on the CPC and the "PRESSN" warning light was illuminated in white at the

[2] MASTER CAUTION: name used by other manufacturers. Here it refers to the central attention getting lamp which is accompanied by a single chime aural alert

bottom of the CWP. No alarm was triggered, and the cabin altitude and differential pressure were normal for the flight level at that time. The cabin vertical speed indicator indicated a rate of climb.

The commander set up a worksplit in the cockpit and started the abnormal situation checklist relating to pressurisation problems, ACL 1.06 Loss of Control of Pressurisation (see Annex 1). He switched the CPC from automatic mode to manual mode. He then performed the abnormal situation checklist ACL 1.08 Manual Control of Pressurisation (see Annex 3) containing the values to be used with the CPC in manual mode and adjust the cabin rate using the "MAN RATE"[3] knob. In the meantime, the co-pilot told the air traffic controller there was a pressurisation problem and requested permission to descend. Flight LX0435 was authorised to descend to flight level FL 230, then FL 190 and FL 100. During the descent, the commander noticed a cabin rate of climb of 3000 ft/min.

Between FL 230 and FL 170 the cabin oxygen masks, hereinafter referred to as "the masks" dropped out. The co-pilot noted that the warning light "PAX OXY OUT" located on the right drop out override switch, was illuminated. To ensure that they had dropped-out correctly, he pressed this switch. While the aircraft was descending between FL 218 and FL 160, the senior flight attendant made an first "EMER CALL"[4] and informed the commander by interphone that the cabin masks had deployed and were being used by the cabin crew and the passengers. The commander confirmed the pressurisation problem. He asked the senior flight attendant to tell the cabin crew and passengers to continue using the masks and to remain seated. Then he notified the co-pilot of the cabin situation and decided that they should both don their oxygen masks.

At 15:20:16 UTC, as the flight was passing FL 160 in descent to FL 100, the co-pilot made a first radio call using the microphone fitted in his mask. The commander was still occupied with manual setting of the cabin rate using the "MAN RATE" knob. He selected a rate of descent of -300 ft/min but the rate fluctuated between -700 and +5000 ft/min.

At 15:22:40 UTC, as the aircraft was passing FL105 in descent to FL 100, the cabin altitude alert "CABIN HI ALT"[5] illuminated in red on the CWP accompanied by an intermittent horn. At the same time a triple chime sounded and the red attention getting lamps located directly in front of the pilots illuminated.

At 15:23:37 UTC the aircraft was maintaining FL 100 and the co-pilot declared an emergency situation to the air traffic controller. He sent the message: "*… we declare PAN PAN due to loss of pressurisation"*. The senior flight attendant made a second "EMER CALL" for the attention of the commander. He stated that a small quantity of smoke was emanating from the oxygen generator housings in seat row no. 10, accompanied by a strong smell in the cabin. Following this call the commander entered the transponder emergency code 7700.

At 15:23:54 UTC the aircraft was leaving FL 100 for FL 80. The "CABIN HI ALT" alert went out as the aircraft was passing FL 99.

At approximately 15:26 UTC, the pilots removed their masks when the aircraft was at FL 80. The commander made an announcement to the passengers and cabin crew stating that they could now remove their masks. He also stated that they

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[3] MAN RATE: manual rate

[4] EMER CALL: emergency call, aural alert requesting the pilot to listen to the cockpit-cabin interphone. It can be activated from the cabin crew workstations.

[5] CABIN HI ALT: cabin high altitude

would be making a normal landing in Geneva in 10 minutes without any special preparations. He told the air traffic controller that the aircraft would remain on the runway after landing to allow inspection of the cabin.

At 15:34:30 UTC, the landing proceeded normally and the aircraft came to a halt on runway 05. The commander ensured that everything was normal in the cabin and that there was no smoke present. He decided that the aircraft could proceed to its parking area, accompanied by the vehicles of the airport security service (SSA). The passengers disembarked the aircraft normally. There were no injuries and nobody required medical assistance.

1.1.4 Location of the serious incident

Location	Near waypoint LUSAR, 50 NM north-west of Geneva airport
Level and phase of flight	Between FL 270 and FL 190, in descent

1.2 Injuries to persons

Injuries	Crew	Passengers	Total number of occupants	Others
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	4	93	97	Not applicable
Total	4	93	97	0

1.3 Damage to aircraft

Ten containers for the cabin oxygen masks had to be replaced.

1.4 Other damage

None

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Commander

Person	Swiss citizen, born in 1976
Licence	Airline Transport Pilot Licence (Aeroplane) – ATPL(A) according to the European Aviation Safety Agency (EASA), first issued by the Federal Office of Civil Aviation (FOCA) on 1 September 2003
Type rating	AVRO RJ/Bae146, pilot-in-command (PIC), valid to 31 July 2013
Ratings	Instrument rating IR(A) Night flying NIT(A) Radiotelephony in English Language proficiency: English Level 4, valid until 31 July 2013
Latest proficiency check	Licence proficiency check (LPC), 27 June 2012
Start of flight training	4 June 1994

The available data indicates that the commander started duty rested and in good health.

1.5.1.1.1 Flying experience

Total hours	5567 hours
Of which on the type involved	2688 hours
In the last 90 days	88 hours
Of which on the type involved	88 hours
During the last 24 hours	6:45 hours
Of which on the type involved	6:45 hours
As pilot in command	1245 hours

1.5.1.2 Co-pilot

Person	German citizen, born 29 April 1987
Licence	Airline Transport Pilot Licence (Aeroplane) – ATPL(A) according to the European Aviation Safety Agency (EASA), first issued by the Federal Office of Civil Aviation (FOCA) on 30 March 2012

Type rating	AVRO RJ/Bae146, valid to 31 May 2013
Ratings	Instrument rating IR(A)
	Night flying NIT(A)
	Radiotelephony in English and German
	Language proficiency: English Level 4, valid until 31 December 2014
Latest proficiency check	Licence proficiency check (LPC), 30 March 2012
Start of flight training	16 November 2006

The available data indicates that the co-pilot started duty rested and in good health.

1.5.1.2.1 Flying experience

Total hours	2138 hours
Of which on the type involved	1930 hours
In the last 90 days	101 hours
Of which on the type involved	101 hours
During the last 24 hours	6:45 hours
Of which on the type involved	6:45 hours

1.6 Aircraft information

1.6.1 General information

Registration	HB-IYY
Aircraft type	AVRO 146 RJ-100
Characteristics	High-wing four-engined airliner
Manufacturer	British Aerospace Regional Aircraft Ltd, United Kingdom
Year of manufacture	1998
Serial no.	E3339
Owner	Swiss International Air Lines Ltd., Postfach, 4002 Basel, Switzerland
Operator	Swiss European Air Lines AG, Malzgasse 15, 4052 Basel, Switzerland
Engines	4 x Allied Signal LF507-1F
Airframe operating hours	32,759 hours
No. of cycles	30,846

Maximum permissible masses	Take-off : 44,999 kg Landing : 40,142 kg
Mass and centre of gravity	The mass and centre of gravity were within the limits prescribed by the aircraft flight manual (AFM)
Maintenance	Periodic C-Check performed at 28,185 hours TSN[6]
Fuel	According to the flight plan, the takeoff fuel was 6100 kg, including trip fuel of 3500 kg
Certificate of registration	Issued by the FOCA on 11 April 2007 and valid until deletion from the register
Certificate of airworthiness	Issued by the FOCA on 11 April 2007
Airworthiness review certificate	Date of issue: 22 March 2013 Date of expiry: 3 April 2014
Scope of utilization	Commercial operation
Categories	Day VFR/night VFR/Category III IFR/B-RNAV (RNP 5)/P-RNAV (RNP 1)

1.6.2 Loads carried

No effect on the serious incident.

1.6.3 Systems of the aircraft involved

1.6.3.1 Pressurisation

The pressurisation system allows certain areas of the aircraft to be maintained at a lower effective altitude than the actual altitude of the aircraft. For example, when the aircraft is at an altitude of 27,000 ft, the cabin is maintained at an effective altitude of 5200 ft. This results in a pressure difference between the external atmospheric pressure and the pressure prevailing inside the cabin, called differential pressure.

Since atmospheric pressure decreases with altitude, it is necessary to compensate for this reduction by feeding compressed air into the cabin. This compressed air is drawn from the engines or the auxiliary power unit (APU). The temperature and flow of the compressed air are regulated by two units known as packs before it is fed into the pressurised areas of the aircraft, in particular the passenger cabin and the cockpit. It is then discharged into the atmosphere through two outflow valves. This process is continuous and allows the air inside the aircraft to be continuously refreshed.

[6] TSN: time since new

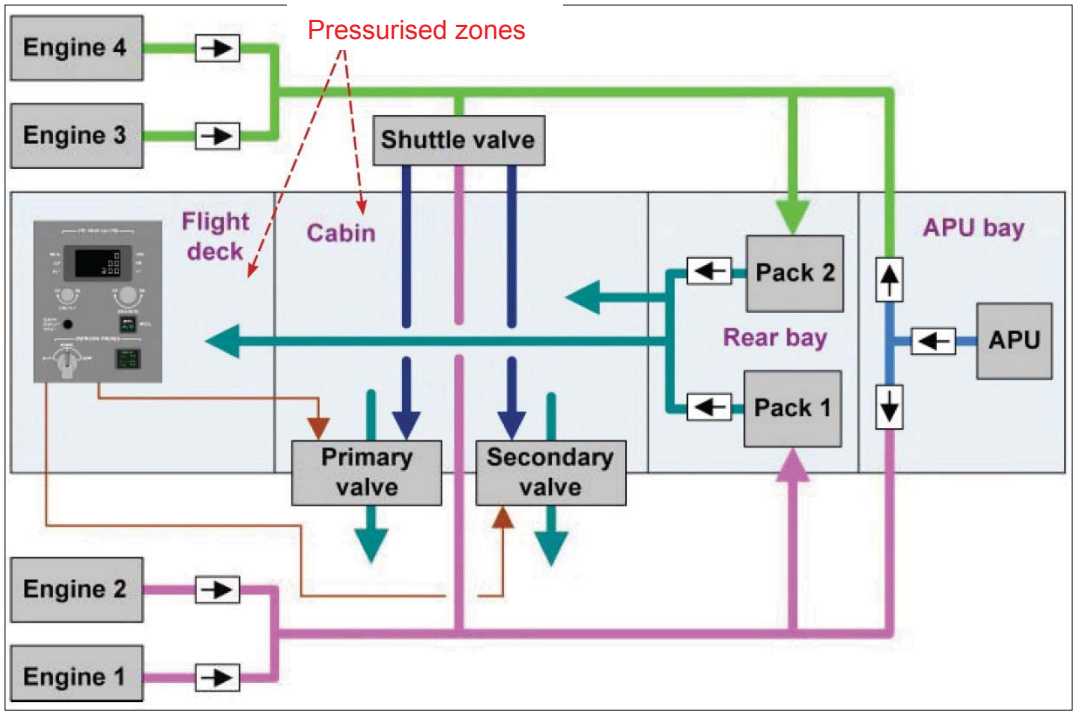

Figure 1: Block diagram of the pressurisation system

1.6.3.2 Pressure controller

A regulator called the cabin pressure controller (CPC) adjusts the opening of the two outflow valves, accurately regulating the cabin pressure by modulating the exhaust air flow. Normally the CPC operates in automatic mode and adjusts the cabin pressure depending on the altitude of the aircraft according to predetermined values.

The CPC has a primary channel (PRI) and a secondary channel (SEC), each having its own reference cabin pressure, plus altitude, altimeter setting and speed information from two independent air data computers (ADC).

Normally the CPC uses the primary channel. In the event of a fault, the CPC automatically switches to the secondary channel.

Figure 2: Cabin pressure controller (CPC)

1.6.3.3 Outflow valves

When the system is not active, the outflow valves are closed by a spring. They are opened by a venturi device called a jet pump, which creates suction in the reference chamber (see Figure 3). The CPC modulates the suction by means of an electropneumatic device, thereby regulating the pressure in the reference chamber (reference chamber pressure).

For the primary valve, the inlet air to create the vacuum comes directly from the cabin through a calibrated orifice (cabin pressure inlet). For the secondary valve, which does not have a cabin pressure inlet, the air comes from the reference chamber of the primary valve through an interconnecting pneumatic pipe (link pipe) connecting the two reference chambers. This pipe is made of aluminium, with a diameter of approximately 10 mm and the two outflow valves are approximately 6 m apart.

When the CPC primary channel performs the regulation, it electrically operates the torque motor of the primary outflow valve and the secondary outflow valve is pneumatically slaved.

When the CPC secondary channel performs the regulation, it electrically operates the torque motor of the secondary outflow valve and the primary outflow valve is pneumatically slaved.

The valve opening position results from the combined actions of the spring, the suction and the pressure in the cabin.

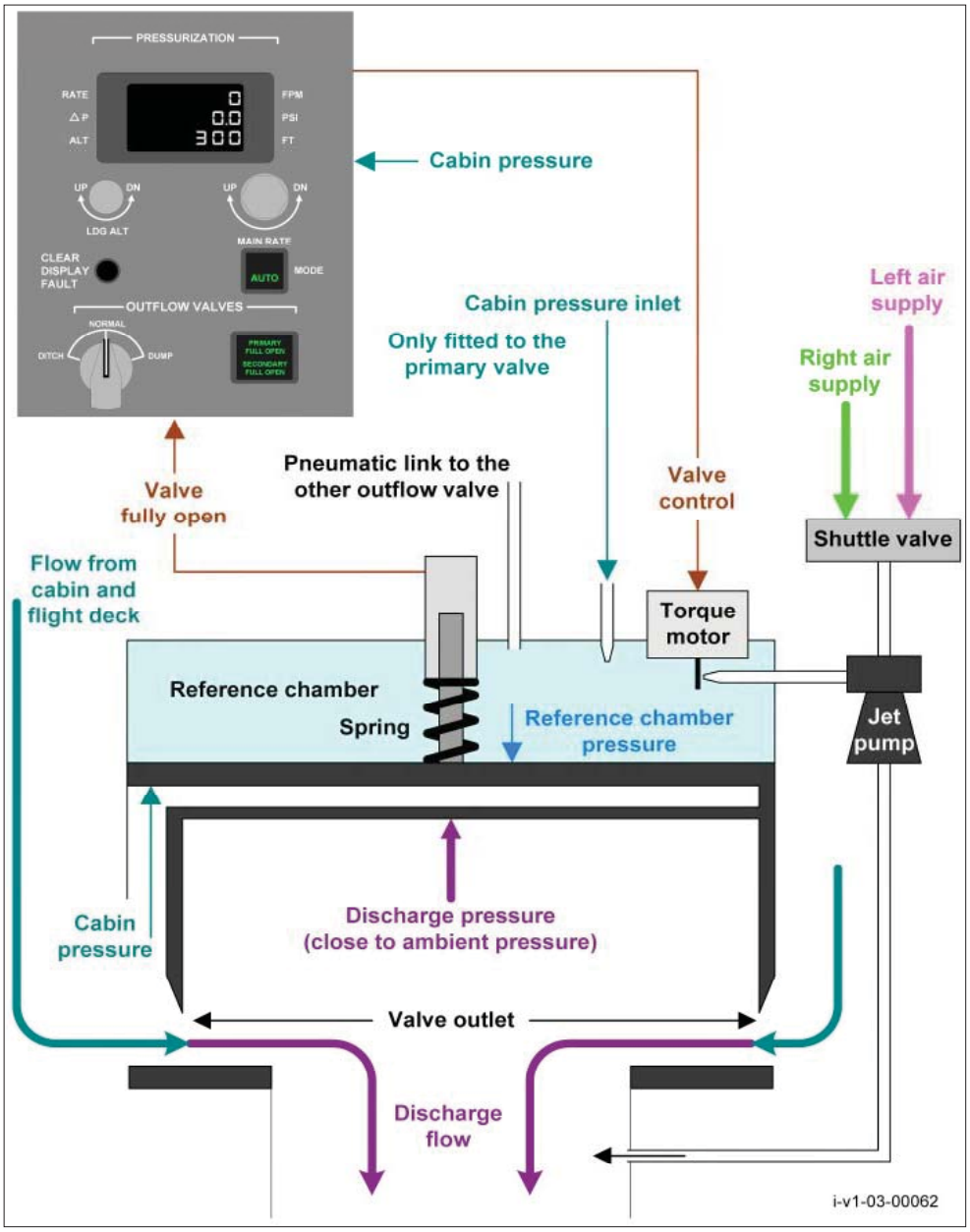

Figure 3: Block diagram of the primary outflow valve

1.6.3.4 Indications in normal operation

In order to check the operation of the CPC the pilots have the following information:

- the cabin vertical speed in ft/min (cabin rate);
- the differential pressure in PSI[7];
- the cabin altitude in ft;
- the altitude in ft of the destination airport (landing altitude).

These parameters are visible on the 3-line liquid crystal display (LCD) of the CPC (see Figures 2 and 3) and on the “QUAD” indicator (see Figure 4) on the right-hand side of the cockpit front instrument panel.

Indications on CPC:

Line 1: the cabin rate of climb or descent.

Line 2: the differential pressure.

Line 3: the cabin altitude or altitude of the destination airport.

The CPC display receives its information only from the secondary channel.

“QUAD” indicator

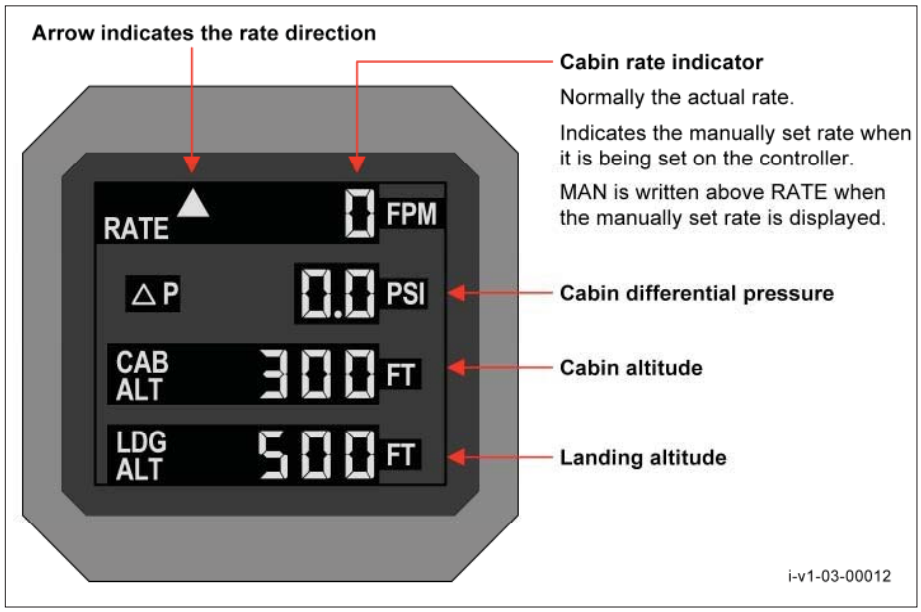

Figure 4: QUAD indicator

In normal operation, the "QUAD" indicator receives its information from the primary channel of the CPC. In the event of failure of the primary channel, the secondary channel provides the information.

[7] PSI: pound-force per square inch

1.6.3.5 Indications in abnormal operation

If the CPC detects a minor problem requiring no action by the flight crew, such as failure of the primary or secondary channel, a white "PRESSN" warning light illuminates at the bottom of the CWP. It also illuminates when the CPC is in manual mode. In addition, an error code replaces the value of the differential pressure on the second display line of the CPC. If the primary channel fails the code "PRI" is displayed. If the secondary channel fails the code "SEC" is displayed. The flight crew should then use the pressurisation controller fault abnormal situation checklist which recommends use of the "CLEAR DISPLAY FAULT" button (see Figure 2) to correctly record the error code(s).

In the event of a CPC problem requiring intervention by the flight crew, such as failure of both channels, an amber "PRESSN↑" warning light illuminates on the CWP. In addition, a single chime aural alert sounds, accompanied by amber attention getting lamps located directly in front of the pilots. In addition, the error code "DUAL" is displayed on the CPC.

1.6.3.6 Control in manual mode

In the event of a problem in automatic mode, the flight crew can select manual mode on the CPC by pressing the "MODE" push-button switch (see Figure 2). They must then adjust the cabin altitude relative to that of the aircraft using a table of values provided in the abnormal situation checklist.

To adjust the cabin altitude, the only manually adjustable value is the rate of climb or descent of the cabin altitude. To do this, the flight crew use the "MAN RATE" rotary adjustment knob (see Figure 2) to select the desired rate. The selected rate then replaces the rate programmed in the channel being used by the CPC at the time of selecting manual mode. The selected rate electrically operates the torque motor of the cabin regulation valve in operation.

The "MAN RATE" knob has 16 adjustment positions with successive increments of 50 ft/min. Movement to the first position switches the current rate displayed on the CPC to the rate chosen by the pilot. The first position corresponds to 0 ft/min. The selected rate is accompanied by arrows indicating climb or descent and by the letters "MR" indicating manual rate. The selected value is displayed for 5 seconds. If the knob is not turned any further, the display returns to the current rate. The checklist for this abnormal situation recommends using a descent rate of 300 ft/min and a rate of climb of 500 ft/min, followed by 0 ft/min once the desired cabin altitude has been reached.

1.6.3.7 CPC protective systems

In automatic mode, the CPC uses a programmed cabin rate. An internal system protecting against excessive rates continuously compares the current rate with the set value. If the difference exceeds a limit value for a certain period, the operating channel, normally the primary, is turned off and the CPC switches to the secondary channel. If the difference persists for the same period, the internal protection system switches back to the primary channel. If the fault is still present, the amber "PRESSN↑" warning light illuminates on the CWP, together with the amber attention getting lamp. In addition, a single chime aural alert sounds and the error code "DUAL" appears on the CPC. If the fault disappears the CPC automatically resumes control and the "DUAL" code disappears.

Each CPC channel has a programmed automatic protection system limiting the differential pressure to 7.36 PSI below FL 270 and 7.46 PSI above FL 270. If these values are reached, the CPC abandons any other mode of regulation and orders

a rate of climb in order to reduce the differential pressure. This automatic protection also works in manual mode. Its activation is not announced.

If the CPC fails to maintain the cabin altitude below 8700 ft, the flight crew is alerted by the flashing cabin altitude warning. If the cabin altitude reaches 9700 ft or higher, the flight crew is warned by a red "CABIN HI ALT" warning light on the CWP accompanied by an intermittent horn. In addition, a triple chime alert sounds, together with the red attention getting lamps located directly in front of the pilots.

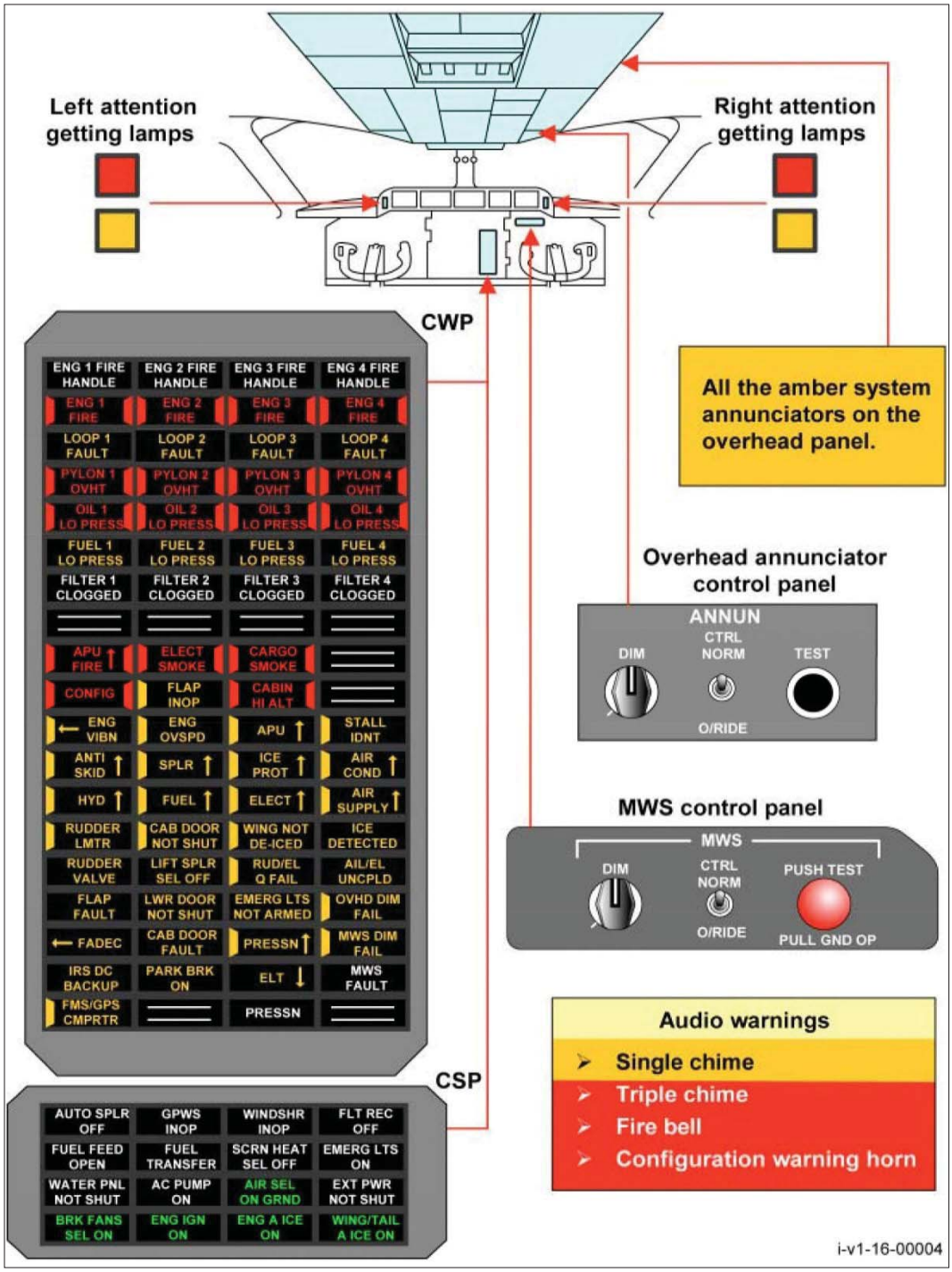

Figure 5: Warning indicators

1.6.3.8 Cabin oxygen system

The aircraft is equipped with oxygen masks for all passengers. They are placed in sets of three in closed containers above each row of seats, and in the ceilings of the toilets and cabin crew galleys. These containers are called passenger service units (PSUs). When cabin pressurisation is operating normally the masks are not visible.

In the event of loss of pressurisation, the cabin altitude increases. If it exceeds the threshold value of 13,250 ft (4039 m), an aneroid capsule automatically sends an

electrical signal to the mask drop out relay (Figure 6, Part B, block diagram). The relay orders opening of the PSUs after a delay of 2 seconds, following which the masks are released. The masks can also be manually dropped out by operating two drop out override switches located on each side of the cockpit (Figure 6, Part A, override switches). They are fitted with a guarded switch which must be raised before the switch can be pressed (Figure 6, Part C, detail of an override switch). Drop out of the masks is indicated by illumination of the switches. In the event of malfunction, each PSU can be opened using a metal manual tool to release the locking system.

Each PSU has an oxygen generator to which the masks are connected by a cord. The oxygen generator is activated when a passenger pulls one of the masks. Once activated, this process cannot be interrupted. It provides oxygen continuously for 13-22 min depending on the generator model. During this period, the aircraft should descend to an altitude allowing passengers to breathe without additional oxygen, normally defined as 10,000 ft. The chemical generation of oxygen releases heat which may cause the surface of the generator to reach a temperature of 205 °C. The passengers receive instruction on use of the masks before each flight.

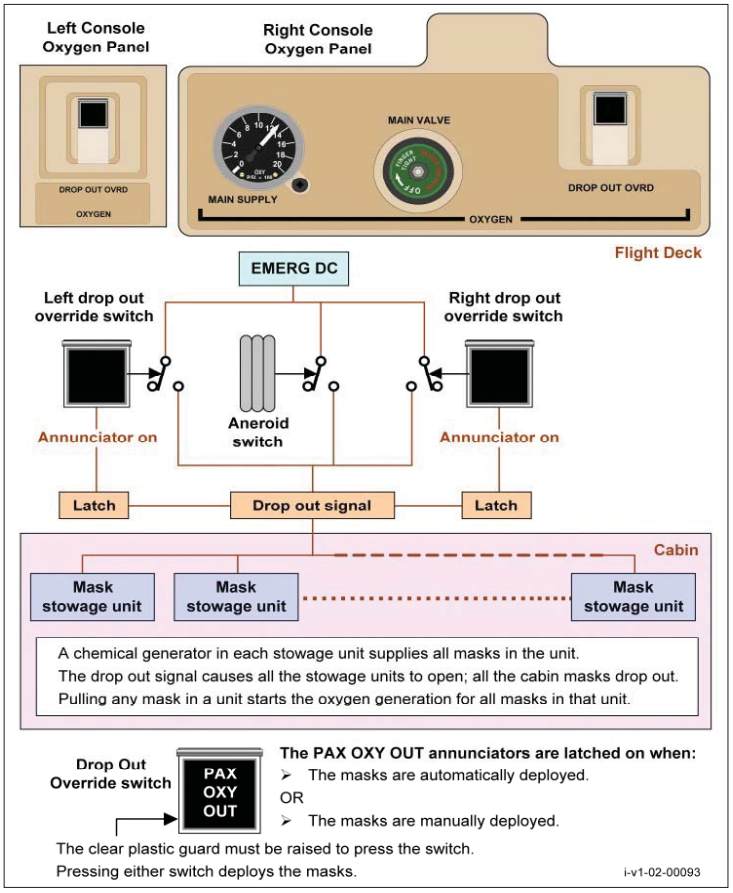

Figure 6: Cabin mask drop out system

1.6.3.9 Flight deck crew oxygen

The two pilots and a possible third person in the cockpit each have an oxygen mask equipped with a microphone allowing them to communicate with each other, the cabin crew and air traffic control. The three masks are connected to a rechargeable oxygen cylinder located in the forward hold.

1.6.4 Maintenance

In addition to routine inspections, the manufacturer's maintenance programme stipulates comprehensive periodic technical checks of the aircraft, of type A, B, C, etc. During these checks, certain components are systematically replaced. Others are inspected and, depending on their condition, are replaced or overhauled and reinstalled. Depending on the changed or reinstalled components, different tests are required before returning the aircraft to service. Between the comprehensive periodic technical inspections, the maintenance personnel will only intervene in response to a crew defect report or if a defect is found during a routine inspection.

The CPC, the outflow valves and their pneumatic connections are inspected and tested as part of each C-check. Similarly, the cabin oxygen mask drop out system is inspected and tested as part of each C-check. The chemical oxygen generators are replaced according to a due date limit, even if they have not been used.

The last periodic C-check was carried out from 9 December 2011 to 1 January 2012. The aircraft had flown 28,185 hours and performed 30,287 cycles.

1.6.4.1 Maintenance work between 8 and 24 March 2013

Following the incident on 8 March 2013 (section 1.1.2.1), the cabin oxygen mask drop out system was repaired and tested before returning the aircraft to service. On this occasion there was no intervention on the outflow valves.

After return to service of the aircraft on 9 March 2013, no defect report relating to the passenger pressurization or oxygen systems was issued prior to 24 March 2013.

1.7 Meteorological information

1.7.1 General

The data in sections 1.7.3 and 1.7.4 is based on observations, radar plots and webcam images.

1.7.2 General situation

A trough of low pressure extended from the centre of the Mediterranean to the Atlantic via the Pyrenees. A low pressure area over Sardinia was bringing heavy cloud cover over the Alps from the south-west. An area of stratus cloud persisted over the Central Plateau. Its upper altitude was 1500 m AMSL. The atmosphere above was cloud-free up to 3600 m AMSL. Above this altitude cloud cover again increased.

From 15:30 UTC, the cloud base continually descended in the region of Lake Geneva and Bas Valais. The dry and cloud-free air of the intermediate zone disappeared around 16:00 UTC. However, due to the influence of the Föhn wind, it remained present in the east.

A moderate Bise wind was blowing over the Central Plateau up to 2000 m AMSL. Above this the wind shifted to the south-west. There was a Föhn wind from the south along the Alps.

The modelling of the cloud distribution over eastern France shows cloud cover between 5/8 and 7/8 between FL 150 and FL 180 and a compact cloud layer from FL 180 to FL 330.

1.7.3 Weather before takeoff from London-City

Cloud	Overcast
Visibility	Greater than 10 km
Wind	070° at 13 kt
Temperature/dewpoint	0 °C/-3 °C
QNH[8]	1013 hPa
Hazards	None

1.7.4 Weather at the time of landing at Geneva

Weather/cloud	Light rain with mist and overcast sky
Visibility	5000 m in mist
Wind	050° at 7 kt
Temperature/dewpoint	4 °C/2 °C
QNH	1003 hPa
Hazards/trend	None/No significant change

1.7.5 Astronomical data

Position of the sun at 15:30 UTC	Azimuth: 246°	Elevation: 23°
Natural lighting conditions	Daylight	

1.7.6 Aerodrome meteorological information

The aviation routine weather report (METAR) for Geneva valid at 15:20 UTC was as follows:

LSGG 241520Z 05007KT 5000 -RA BR OVC020 04/02 Q1003 NOSIG=

In plain text, this means:

On 24 March 2013, the following weather observations were made shortly before the publication of the METAR for Geneva airport:

[8] QNH: pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere

Wind	050° at 7 kt
Meteorological visibility	5000 m in mist
Precipitation	Light rain
Cloud	8/8, sky overcast
Temperature	4 °C
Dewpoint	2 °C
Atmospheric pressure	1003 hPa
Trend	No significant changes expected within the two hours following the weather information

1.8 Aids to navigation

Not applicable

1.9 Communications

Radio communications between the pilots and the air traffic control services were normal. Transmission quality was slightly degraded when the pilots were wearing oxygen masks.

1.10 Aerodrome information

1.10.1 General

Geneva airport is located in western Switzerland. The reference elevation is 1411 ft AMSL and the reference temperature is 24.8 °C.

1.10.2 Runways

Designation and surface	Dimensions	Equipment
23/05 – concrete	3900 x 50 m	23 - ILS Cat III and 05 - ILS Cat I
23/05 – grass	823 x 30 m	23 - APAPI 4.5° and 05 - APAPI 4°

1.10.3 Rescue and fire-fighting services

Geneva airport is equipped with category 9 firefighting resources. The firefighting personnel are professional and are on call 24 hours a day.

1.11 Flight recorders

1.11.1 Flight data recorders

Type	SSFDR P/N 980-4700-003
Manufacturer	Honeywell

The data from the flight data recorder (FDR) was legible and usable.

1.11.2 Cockpit voice recorder

Type	SSCVR P/N 980-6022-001
Manufacturer	Honeywell

The recording of the cockpit conversations could not be used as the power supply to the cockpit voice recorder (CVR) was not cut soon enough after landing. The recording time is limited to 2 hours and after this time, the system starts recording again, overwriting the previous recording.

1.12 Wreckage and impact information

Not applicable

1.13 Medical and pathological information

Not applicable

1.14 Fire

Fire did not break out. The use of the chemical oxygen generators for the passenger masks resulted in a significant release of heat. The surface temperature of the generators can reach 205 °C and 10 PSUs were deformed due to heat, requiring their replacement. A slight release of smoke occurred in the mask housings in row 10.

1.15 Survival aspects

When the cabin altitude exceeds 9700 ft the red "CABIN HI ALT" warning light illuminates. According to the FDR, it illuminated as the aircraft was passing FL 105 in descent and went off approximately a minute and fifteen seconds later when the aircraft was passing FL 99.

The commercial regulations do not require the use of oxygen if the cabin altitude is between 10,000 ft and 13,000 ft for less than thirty minutes.

1.16 Tests and research

Following the serious incident, the airline's maintenance company immediately conducted tests and research on the origin of the problems relating to pressurisation and the failure of drop out of oxygen masks.

These tests and research revealed in particular:

- that the pressurisation system tests were not satisfactory;
- the presence of a significant amount of water due to condensation in the pneumatic link pipe between the outflow valves;
- the presence of a small amount of water due to condensation in the pneumatic pipes supplying air to the jet pumps;
- excessive friction slowing down the opening and closing of the secondary outflow valve;
- the absence of defects in the wiring of the pressurisation system and passenger mask drop out system;
- the absence of defects in the aneroid safety capsule and its wiring;
- that the passenger masks in seat rows 2 (seats DEF), 3 (seats DEF), 14 (seats DEF) and 16 (seats DEF) were not connected to their oxygen generators;

- that the PSUs for seat row 3 (seats DEF) and for the front galley did not open;
- the presence of dust on one oxygen generator in the PSU for seat row 10.

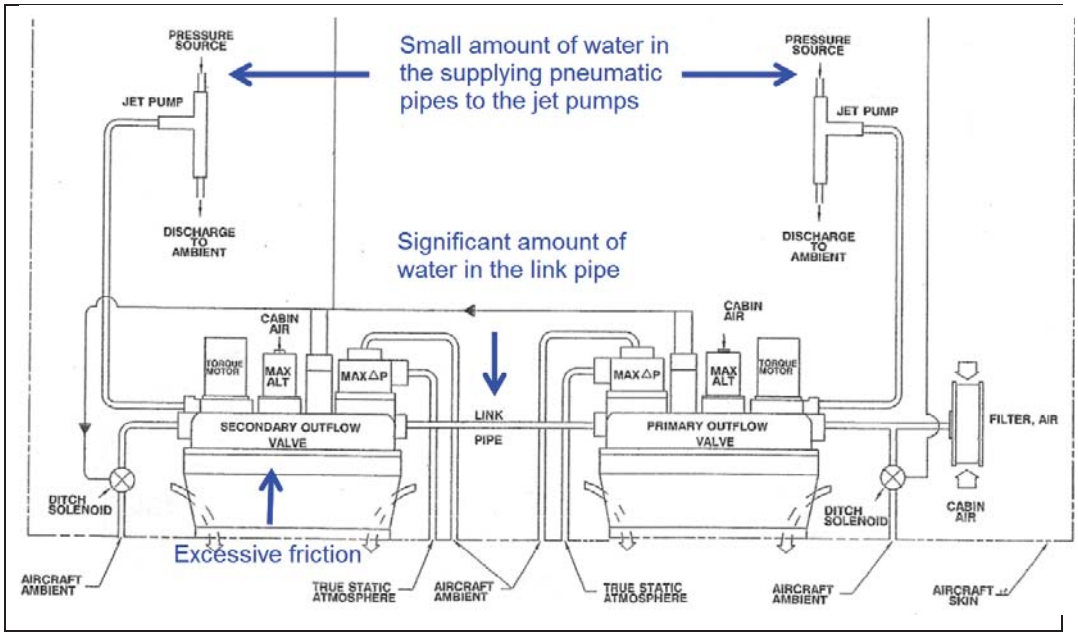

Figure 7: Diagram of the pneumatic connections of the outflow valves

In addition, the maintenance company identified the pneumatic pipes and pneumatic regulator of the outflow valves as the components most exposed to moisture and freezing.

1.17 Organisational and management information

Swiss European Air Lines is a wholly-owned subsidiary of the parent company Swiss International Air Lines, the latter having decided in 2005 that regional flights would be carried out by a company separate from the parent company. The Air Operator Certificate *(*AOC) of Swiss European Air Lines was issued by the FOCA on 1 November 2005.

At the time of the serious incident, Swiss European Air Lines was operating twenty AVRO 146-RJ100 aircraft. The line maintenance and maintenance up to type A inspections was carried out by Swiss. Base maintenance and maintenance up to C-checks was outsourced.

The latest C-check on HB-IYY was carried out by Lufthansa Technik Switzerland (LTSW) at Bâle-Mulhouse airport from 9 December 2011 to 1 January 2012. LTSW ceased operations at Bâle-Mulhouse in April 2013, resulting in redundancies among the technicians.

1.18 Additional information

1.18.1 Entry of the pressurisation problem in the technical log

After landing, the commander reported the problem encountered during the flight in the technical log. He mentioned *inter alia* that the white “PRESSN” warning light and the “PRI” error code on the CPC display were present before selection of the CPC manual mode.

The crew also stated that they quickly switched to manual mode after the appearance of the “PRI” code on the CPC.

1.18.2 Work carried out following the serious incident of 24 March 2013

The following work was carried out before allowing the aircraft to return to service:

- the two outflow valves were replaced;
- the pneumatic pipes were cleaned;
- the CPC was replaced as a precautionary measure;
- all the passenger masks and oxygen generators were replaced.

Three tests were carried out successfully after the work:

- a test of the pressurisation system;
- a test of the drop out of the passenger masks;
- a test flight.

1.18.3 Quality control

The technical division of the company quality control service conducted an internal investigation into the fact that some PSUs remained closed and certain masks were not connected to their oxygen generator.

The findings mention installation errors during the work carried out following the incident of 8 March 2013, outsourced work during the night of 8 to 9 March 2013 (previous incidents, section 1.1.2.1). They were attributed mainly to tiredness, a lack of time and personnel, and to a defective independent inspection procedure.

1.19 Useful or effective investigation techniques

Not applicable

2 Analysis

2.1 Technical aspects

2.1.1 First flight on 24 March 2013: Geneva-Nice

During the climb, water due to condensation was certainly already present in the pneumatic suction and link pipes connected to the outflow valves. This could have interfered with operation of the primary channel of the CPC. The CPC switched to the secondary channel and displayed the “PRI” error code. The secondary channel encountered the same problems and also ceased to operate, which momentarily activated the attention getting lamp. As the flight crew had not switched the system to manual mode, the CPC again switched to the primary channel which this time was able to resume control in automatic mode. The “PRI” and “SEC” error codes (section 1.1.2.2) and the autonomous extinction of the central alarm confirm this sequence.

The cruising flight level was lower than that during the serious incident flight. The flight time was significantly shorter and the outside temperature at Nice was positive. The flight from Nice to Geneva was therefore uneventful. After landing at Geneva where the outside temperature was also above zero, the satisfactory test of the CPC allowed the flight to London-City to be made as scheduled. No problem was reported during this flight.

2.1.2 CPC and cabin outflow valves

Normally, the primary channel of the CPC regulates cabin pressure. It electrically controls the torque motor of the primary outflow valve. The secondary outflow valve is pneumatically slaved by the primary outflow valve.

After the serious incident flight, a significant amount of water due to condensation was found in the link pipe between the outflow valves. The aircraft was flying for a sufficiently long duration at a temperature well below zero for this water, or part of it, to freeze. Following the descent from FL 310 to FL 270, frozen water could have obstructed the link pipe and caused a malfunction in the pneumatic control system between the outflow valves. In addition, the excessive friction reported in the secondary outflow valve also interfered with its operation. These two factors could have caused erratic movements of the secondary outflow valve, causing cabin climb or descent rates not corresponding to the CPC set values and perceived as unusual by the crew. As the primary channel was not able to hold these set values, the system protecting against excessive CPC rates switched to the secondary channel. This was confirmed by the PRI error code and the white “PRESSN” warning light as reported by the commander.

The flight crew confirmed that no alarm had been activated and did not mention a “DUAL” error code on the CPC. This fact indicates: either that the secondary channel was operating normally after the switchover by the CPC, or that it was defective but the switchover to manual mode by the commander occurred before activation of the system protecting against excessive climb or descent rates.

The CPC was switched to manual mode when the primary channel was inactive. Therefore the rates set by means of the “MAN RATE” knob electrically operated the torque motor of the secondary outflow valve and the primary outflow valve would have been slaved pneumatically. The fact of using a selected rate instead of a rate programmed in the CPC does not change the regulation principle of the outflow valves. The water in the pneumatic pipes and the excessive friction in the secondary outflow valve also interfered with the manual mode. The erratic response of the system in manual mode could have resulted in activation of the automatic protection limiting the differential pressure. This protection orders a rate of

climb. It is always present and has priority over all the other functions; its activation is not announced.

2.1.3 Cabin oxygen masks

The non-opening of certain PSUs and the non-activation of certain chemical oxygen generators were due to installation errors essentially linked to human factors.

The main components used for drop out of the masks were changed on 9 March 2013. Checking the wiring of the drop out system did not reveal any defects. No problem was subsequently reported afterwards. The tests carried out just after the serious incident on the wiring of the whole mask drop out system were satisfactory.

Analysis of the FDR data indicated that the cabin altitude did not exceed 10,200 ft. It would have had to exceed 13,250 ft to cause drop out of the masks by means of the aneroid capsule. The investigation could not establish with certainty the reason for the automatic drop out of the cabin oxygen masks.

2.1.4 Smoke release above seat row 10

This smoke was caused by the combustion of dust on one oxygen generator.

2.2 Human and operational aspects

Trusting their sensory perceptions, the flight crew began processing a checklist for an abnormal situation although no alarm was active at the time, the “PRI” error code was displayed on the CPC and the white “PRESSN” warning light was illuminated at the bottom of the CWP. This situation indicates that the CPC was operating with the secondary channel and this did not require intervention by the crew other than to note the error code on the CPC. The investigation could not accurately establish the exact moment at which the CPC was switched to manual mode by the commander. Likewise it was not able to establish whether, as in the case of the first Geneva-Nice flight on 24 March 2013, the system would have continued to operate correctly without switching to manual mode. However, this appears unlikely in view of the reported anomalies and the fact that the regulation of the outflow valves is the same in manual mode.

When setting the CPC to manual mode, the first click of the rotary knob for adjusting the climb or descent rate switches the CPC display from the current cabin rate to the rate selected by the pilot, and this first position corresponds to 0 ft/min. The rate selected remains displayed for 5 seconds, then the current rate is displayed once more. The pilot must then verify whether his action has had the expected effect or not. The checklist for this abnormal situation recommends selection of a descent rate of 300 ft/min and a rate of climb of 500 ft/min, then selection of 0 ft/min once the desired cabin altitude has been reached. Even when the system is operating correctly in manual mode, this procedure requires a good deal of the crew’s attention and resources in order to synchronise the cabin altitude with the descent of the aircraft. In addition, the non-simultaneous display of the current rate and selected rate constitutes an additional difficulty. In the case of this serious incident, the system did not respond as expected and required even more monitoring. A rate of climb ordered by a possible unannounced activation of the protective system limiting the differential pressure further increased the difficulty experienced by the crew in analysing the situation.

The cabin altitude never reached the value for automatic drop out of the cabin oxygen masks. The entire automatic drop out system operated correctly during the tests carried out after landing. It cannot be ruled out that one of the override switches in the cockpit for initiating cabin oxygen mask drop out was pressed.

The decision of the flight crew to don oxygen masks although the cabin altitude had not yet reached 9700 ft was taken on the basis of the information received by the commander concerning the masks deployed in the cabin. Considering the uncertainty surrounding the nature of the problems at that time, this decision was appropriate.

The “CABIN HI ALT” warning light illuminated while the aircraft was passing FL 105 in descent. At no point did the cabin altitude ever reach a value which was dangerous for the occupants.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The last C-check was carried out from 9 December 2011 to 1 January 2012 at 28,185 hours TSN.
- An inadvertent drop out of the cabin oxygen masks occurred during cruising flight on 8 March 2013.
- On 24 March 2013, during the first flight between Geneva and Nice, the codes “PRI” and “SEC” were displayed during the climb, together with activation of an amber attention getting lamp.
- The amber attention getting lamp went out without intervention on the part of the crew.
- The company investigation revealed friction which slowed the movement of the secondary outflow valve.
- The manual mode of the CPC does not change regulation of the outflow valves.
- When the CPC is in manual mode, the selected rate of climb or descent is displayed for 5 seconds, then the display reverts to the current rate.
- The protective system preventing excessive changes in cabin pressure automatically switches the CPC channel in use to the other channel.
- The protective system limiting the differential pressure orders a rate of climb. It is always present, but its activation is not indicated to the crew.
- The company investigation revealed that some masks were not correctly installed in their PSUs.
- The company investigation revealed that some masks were not connected to their oxygen generators.
- The tests carried out after the incident on all the cabin oxygen mask drop out components were satisfactory.
- The investigation could not establish with certainty the reason for the automatic drop out of the cabin oxygen masks.

3.1.2 Human aspects

- The documents supplied show that the pilots were in possession of the appropriate licences.
- There is no evidence to suggest that their state of health was affected at the time of the serious incident.
- The company investigation revealed that the installation errors which occurred during the remedial and precautionary actions carried out following the inadvertent drop out of the masks on 8 March 2013 were mainly due to human factors.
- The flight crew initiated a checklist for an abnormal situation on the basis of their sensory perceptions.
- In manual mode the flight crew does not have access to simultaneous display of the selected rate and the current cabin rate.
- The maximum cabin altitude reached was not dangerous for the occupants.

- The passengers disembarked the aircraft normally and no one required medical attention.

3.1.3 Sequence of the flight

- At approximately 15:10 UTC, at FL 270, the pilots perceived a variation in the cabin pressure.
- The error code “PRI” was displayed on the CPC with illumination of the “PRESSN” warning light on the CWP. No other alerts were indicated.
- The differential pressure and cabin altitude were normal for the flight level at that time. The cabin vertical speed indicator indicated a rate of climb.
- The flight crew attempted to regulate the cabin pressure variations using the “MAN RATE” control.
- During the descent, the commander noticed a cabin altitude rate of climb of 3000 ft/min.
- During the descent, the cabin oxygen masks dropped out.
- The co-pilot noticed that the “PAX OXY OUT” warning light on the right-hand side drop out override switch was illuminated and pressed it.
- At 15:20:16 UTC, the co-pilot made an initial radio call using the microphone fitted in his oxygen mask.
- At 15:22:40 UTC, while the aircraft was passing FL 105 in descent to FL 100, the “CABIN HI ALT” warning light illuminated and went out a minute later.
- At 15:23:37 UTC the aircraft was maintaining FL 100 and the co-pilot announced an emergency situation and transmitted the message: “*… we declare PAN PAN due to loss of pressurisation”*.
- At approximately 15:26 UTC the pilots removed their masks when the aircraft was at FL 80.
- At 15:34:30 UTC, the landing was carried out normally and the aircraft came to a halt on runway 05.

3.1.4 General conditions

- The aircraft spent approximately 90 minutes at an altitude where the temperature was well below zero, and this could have caused the water in the pneumatic pipes to freeze.

3.2 Cause

The serious incident was due to a loss of control of the pressurisation system, which was probably caused by the presence of ice in the pneumatic pipes of the cabin regulation valve control system and excessive friction degrading operation of the secondary cabin regulation valve.

4 Safety recommendations, safety advices and measures taken since the serious incident

4.1 Safety recommendations

None

4.2 Safety advices

None

4.3 Measures taken since the serious incident

The company has implemented an additional regular inspection of the pneumatic pipes and outflow valves as part of the maintenance schedule for its fleet of aircraft of the same type.

Payerne, 19 April 2016 Investigation Bureau STSB

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014).

Berne, 12 May 2016

Annexes

Annex 1: Abnormal situation checklist (abnormal checklist – ACL) 1.06

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

Control regained
END

?

Control not regained
Go to appropriate procedure on Page 1.07

Control regained
Continue in manual control
Notes on manual control on Page 1.08

Pressurization Controller Failure

PRESSN ↑

PRESSURIZATION ..... MAN
Attempt to control

?

Control not regained
Go to appropriate procedure on Page 1.07

Control regained
Continue in manual control
Notes on manual control on Page 1.08

Pressurization Controller Fault

PRESSN

Pressurization ..... Confirm operating correctly
MODE and OUTFLOW VALVES ..... Selected as required
Check the controller differential pressure display line.
If a fault is indicated

- Record the fault.
- Press CLEAR DISPLAY FAULT
- Record the next fault.
- Continue this sequence until differential pressure is displayed.

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Annex 2: Abnormal situation checklist (abnormal checklist – ACL) 1.07

Loss of Control of Pressurization Sub-procedures
(Only to be used when directed by another procedure)

Cabin Altitude Low (Diff Pressure High)

Pressure can only be reduced by reducing the flow from the packs into the cabin
Flow can be reduced by:

- Reducing N_2
- Selecting PACK(S) OFF
- Operating in RECIRC

If APU AIR is OFF, RECIRC is not available if only one PACK is ON
If APU AIR is ON, RECIRC is available if one or both packs are ON
For the descent:

- Aim to achieve zero Δp in the last few thousand feet (but below 10 000 ft aircraft altitude)
- Then set PACKS OFF and OUTFLOW VALVES to DUMP
- Then keep aircraft rate of descent low for PAX comfort (ideally < 500 ft/min)

Cabin Altitude High (Diff Pressure Low)

CABIN AIR ..... FRESH
If CABIN HI ALT caption illuminates, Go to **Cabin High Altitude** procedure
⇦ Page 1.04
Before landing:
Packs 1 and 2..... OFF
OUTFLOW VALVES ..... DUMP

1.07 E3339 Oct 26/07 **1.07**

Annex 3: Abnormal situation checklist (abnormal checklist – ACL) 1.08

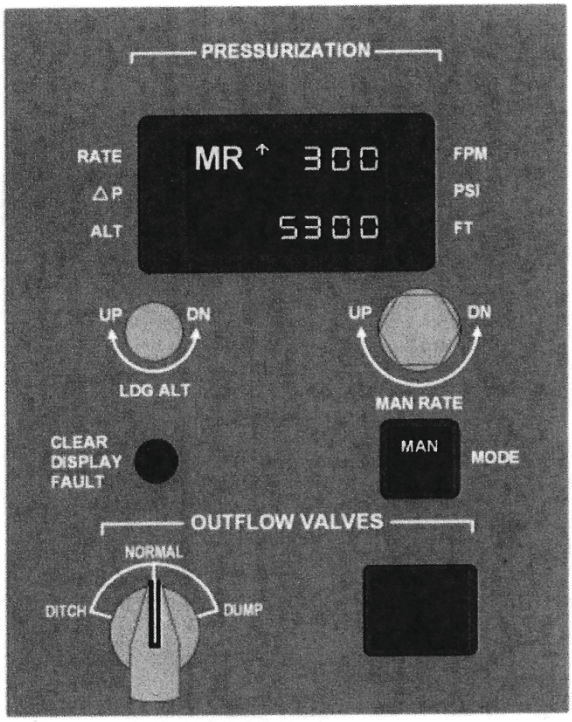
Manual Control of Pressurization

MR rate is selected rate. The controller will change altitude at a pressure rate equivalent to the set rate at sea level.

When MR is not displayed, the actual rate of change of cabin altitude is shown.

At zero cabin alt, the actual rate will be the same as the set rate.

The actual cabin rate increases with cabin altitude; at 8 000 ft cabin alt, the actual rate will be about 20% higher than the set rate.



Change rate with MAN RATE control.

While rate is being set and for 5 sec afterwards, MR and the set rate are shown on the RATE line.

For passenger comfort, keep set rate to between 300 FPM DN and 500 FPM UP.

Set rate to zero when desired cabin altitude is reached.

Cabin altitude for cruise altitude is given in the table below.

Select manual by pressing MODE switch; MAN illuminates.

If automatic transition to manual has been made, MAN will be lit.

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Cabin Altitude for Aircraft Cruise Altitude in Manual Mode					
Aircraft Alt (ft)	**Cabin Alt (ft)**	**Aircraft Alt (ft)**	**Cabin Alt (ft)**	**Aircraft Alt (ft)**	**Cabin Alt (ft)**
0	0	12 000	1 500	24 000	4 200
1 000	100	13 000	1 600	25 000	4 500
2 000	200	14 000	1 800	26 000	4 900
3 000	400	15 000	1 900	27 000	5 200
4 000	500	16 000	2 100	28 000	5 500
5 000	600	17 000	2 300	29 000	5 600
6 000	700	18 000	2 600	30 000	6 100
7 000	900	19 000	2 800	31 000	6 500
8 000	1 000	20 000	3 100	32 000	6 900
9 000	1 100	21 000	3 300	33 000	7 300
10 000	1 200	22 000	3 600	34 000	7 700
11 000	1 400	23 000	3 900	35 000	8 000

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