

الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY



Air Accident Investigation Sector

Incident

- Final Report -

AAIS Case N°: AIFN/0004/2018

Slow Cabin Depressurization during Descent

Operator:	Etihad Airways
Make and Model:	Airbus A320-232
Nationality and Registration:	The United Arab Emirates, A6-EIF
Place of Occurrence:	Karachi FIR, 45 nautical miles west-southwest of Karachi International Airport
State of Occurrence:	Pakistan
Date of Occurrence:	5 March 2018



Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

Incident Brief

AAIS Case N°:	AIFN/0004/2018
Operator:	Etihad Airways
Aircraft make and model:	Airbus A320-232
Registration mark:	A6-EIF
Manufacturer serial number:	3004
Number and type of engines:	Two, IAE V2527-A5 Turbofan engines
Date and time (UTC):	5 March 2018, at 1337 UTC
Place:	Karachi FIR, 45 nautical miles west-southwest of Karachi International Airport
Category:	Transport (Passenger)
Persons on-board:	82
Injuries:	Nil

Investigation Objective

This Investigation was conducted by the Air Accident Investigation Sector (AAIS) pursuant to the United Arab Emirates (UAE) *Federal Act No. 20 of 1991*, promulgating the *Civil Aviation Law, Chapter VII – Aircraft Accidents*, Article 48. It complies with the UAE *Civil Aviation Regulations (CARs), Part VI, Chapter 3*, in conformity with *Annex 13 to the Convention on International Civil Aviation*, and in adherence to the *Air Accidents and Incidents Investigation Manual*.

The sole objective of this Investigation is to prevent aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or determine liability.

This Final Report is structured according to the format contained in *Annex 13* to serve the purpose of this Investigation. The information contained in this Report is derived from the data collected during the Investigation of the Incident.

This Final Report is made public at:

<http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx>

Investigation Process

The occurrence involved an Airbus A320-232 aircraft, registration A6-EIF, and was notified by the Pakistan Safety Investigation Board (SIB) to the AAIS by email. The Pakistan SIB, as the representation of the State of Occurrence, delegated the investigation to the AAIS as of being the investigation authority of the State of Registry and the State of the Operator.

The occurrence was initially classified as a 'Serious Incident' after the initial investigation phase. However, the occurrence classification was changed to an 'Incident' based on the reviewed severity.



The scope of the investigation into this incident is limited to the events leading up to the occurrence; no in-depth analysis of non-contributing factors or non-safety related issues was undertaken.

Notes:

- ¹ Whenever the following words are mentioned in this Final Report with the first letter capitalized, they shall mean the following:
 - (Aircraft) – the aircraft involved in this incident
 - (Commander) – the commander of the incident flight
 - (Co-pilot) – the co-pilot of the incident flight
 - (Incident) – this investigated incident referred to on the title page of this Report
 - (Investigation) – the investigation into this incident
 - (Operator) – Etihad Airways (operator of the aircraft)
 - (Report) – this incident investigation Final Report.
- ² Unless otherwise mentioned, all times in this Report are 24-hour clock in Coordinated Universal Time (UTC), (UAE Local Time minus 4).
- ³ Photos and figures used in this Report are taken from different sources and are adjusted from the original for the sole purpose to improve clarity of the Report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast or insertion of text boxes, arrows or lines.



Abbreviations

AAIS	The Air Accident Investigation Sector of the United Arab Emirates
ACC	Area control center
ACM	Air cycle machine
ADIRS	Air data/inertial reference system
ALT	Altitude
AMM	<i>Aircraft maintenance manual</i>
AOC	Air operator certificate
APT	Airbus procedures training
ARC	Airworthiness review certificate
ATC	Air traffic control
ATPL	Air transport pilot license
AUTO	Automatic
BARO	Barometric
BRK	Brake
CAB	Cabin
CAR	<i>Civil Aviation Regulations</i> of the United Arab Emirates
CAT	Category
CMM	<i>Component maintenance manual</i>
CMS	Centralized maintenance system
CPC	Cabin pressure controller
CPCS	Cabin pressurization control system
CPDLC	Controller/pilot datalink communication
CTL	Control
CVR	Cockpit voice recorder
DDL	Deferred defect list
DFDR	Digital flight data recorder
DI	Descent internal
DIFF	Differential
DME	Distance measuring equipment
DN	Down
ECAM	Electronic centralized aircraft monitoring
ECP	ECAM control panel
ECS	Environmental control system
EIU	Engine interface unit
ELEC	Electrical, electronic



ELEV	Elevation
ELP	English language proficiency
ENG	Engine
EXCESS	Excessive
FCOM	<i>Flight crew operating manual</i>
FFS	Full flight simulator
FL	Flight level
FMS	Flight management system
FMGC	Flight management and guidance computer
FMGS	Flight management and guidance system
ft	Feet
GCAA	The General Civil Aviation Authority of the United Arab Emirates
HI	High
HPV	High pressure valve
IC	Integrated circuit
ICAO	International Civil Aviation Organization
IDF	Intermittent digital failure
IGN	Ignition
ILS	Instrument landing system
IPC	<i>Illustrated parts catalogue</i>
IR	Instrument rating
L	Left hand side
LDG	Landing
LFES	Landing field elevation selector
LGCIU	Landing gear control interface unit
LO	Low
mbar	millibar
MAN	Manual
MAX	Maximum
M/E	Multiple engines
MEA	Minimum enroute altitude
MEL	<i>Minimum equipment list</i>
MHz	Megahertz
MPA	Multi-pilot aircraft
MPL	Multi crew pilot license
No.	Number



NVM	Non-volatile memory
OEM	Original equipment manufacturer
OFV	Outflow valve
OM	<i>Operations manual</i>
OXY	Oxygen
PCSW	Pressure control status word
PF	Pilot flying
PFR	Post flight report
PM	Pilot monitoring
P/N	Part number
PR	Pressure, pressurization
PRESS	Pressure, pressurization
PRV	Pressure regulated valve
QAR	Quick access recorder
QRH	<i>Quick reference handbook</i>
R	Right, right side
RAM	Random access memory
RNAV	Area navigation
RPCU	Residual pressure control unit
SD	System/status display
SEP	<i>Safety equipment procedures</i>
SEU	Single event upset
SEL	Selection
SEL	Single event latch-up
SID	Standard instrument departure
SOP	<i>Standard operating procedure</i>
SPD	speed
SRD	<i>System requirement document</i>
SYS	System
SV	Safety valve
THR	Thrust, throttle
TSM	<i>Trouble shooting manual</i>
UAE	The United Arab Emirates
UTC	Coordinated Universal Time
V/S	Vertical speed

Synopsis

On 5 March 2018, an Etihad Airbus A320-232, registration mark A6-EIF, operated a scheduled passenger flight EY200, from Abu Dhabi International Airport to Karachi International Airport. A total of 82 persons were on-board, comprising 76 passengers, two flight crewmembers, and four cabin crewmembers.

After takeoff and climb, the Aircraft cruised at FL370 and the flight proceeded normally. During the descent, as the Aircraft passed 28,300 feet pressure altitude, the flight crew noticed that the cabin altitude was increasing at a rate of about 300 feet per minute. The flight crew decided to level off at FL270 in order to check if there was any improvement in the cabin altitude. No improvement was evident and the cabin altitude continued to increase. The Commander then commenced an emergency descent, and the Co-pilot informed Karachi area control center (ACC) that EY200 was performing an emergency descent due to a cabin pressure failure, and he declared a PAN-PAN.

As the Aircraft passed through 19,200 feet pressure altitude, an excessive cabin pressure altitude ('EXCESS CAB ALT') warning triggered on the electronic centralized aircraft monitoring (ECAM). During the emergency descent, the cabin altitude rose above 10,000 feet, and the flight crew decided to deploy the passenger oxygen masks manually as the Aircraft was passing approximately 16,400 feet pressure altitude. The Commander then instructed the passengers to use the oxygen masks. The cabin crewmembers ensured that all passengers used the masks.

When the Aircraft descended below 10,000 feet pressure altitude, the flight crew completed the emergency descent, cancelled the PAN-PAN, and informed the cabin manager that the passengers could remove their oxygen masks. The flight then proceeded to its destination and the crew performed an instrument landing system (ILS) approach to runway 25L at Karachi International Airport. The Aircraft landed uneventfully.

The Air Accident Investigation Sector determines that the cause of the Incident was the slow depressurization of the cabin during descent due to the number one cabin pressure controller (CPC1) processing corrupt landing field elevation data. The corrupt value for the landing field elevation was, most probably, caused by a bit corruption in the memory cell of the digital electronic system of the CPC1, which led the flight crew to carry out an emergency descent and to manually deploy the passenger oxygen masks.

The Air Accident Investigation Sector identifies the following contributing factors to the Incident:

- CPC1 as the system that was controlling the cabin pressure control system did not trigger an excessive cabin pressure warning while controlling the cabin towards higher altitude of the landing field elevation, with a cabin altitude rate of 300 to 400 feet per minute. However, the CPC2 triggered the excessive cabin altitude warning when the cabin altitude reached the warning threshold. The landing field elevation used by CPC2 was 96 feet, which was approximately the Karachi International Airport elevation.
- The corrupted memory was, most probably, caused either by a single event upset (SEU) in one memory cell of CPC1, or by erroneous data caused by fatigued solder joints on the ICs of the main board of the CPC1.

The AAIS issued two safety recommendations: one to the Operator, and one to the Aircraft manufacturer.



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1. Factual Information

1.1 History of Flight

On 5 March 2018, an Etihad Airbus A320-232, registration mark A6-EIF, operated a scheduled passenger flight EY200, from Abu Dhabi International Airport (OMAA¹) to Karachi International Airport (OPKC²). There were a total of 82 persons on-board, comprising 76 passengers, two flight crewmembers, and four cabin crewmembers.

The Aircraft was pushed back from parking stand 303 at about 1201 UTC. The Commander was the pilot flying (PF) and the Co-pilot was the pilot (PM).

ATC provided instructions for a standard instrument departure from runway 31R, via KANIP 1N. After the Tower provided take-off clearance including the wind surface information, the Aircraft entered runway 31R at 1216:05 and performed a rolling takeoff.

Figure 1 shows the flight path of the Aircraft from OMAA to OPKC.

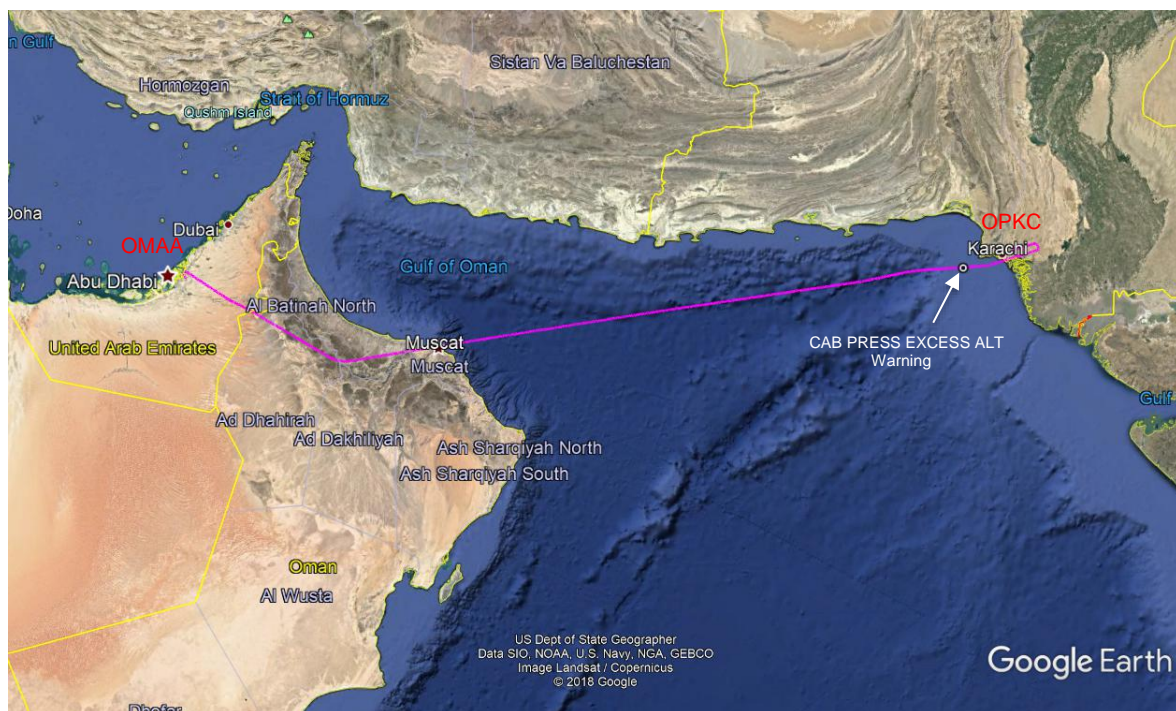


Figure 1. Flight path on google earth – from Abu Dhabi (OMAA) to Karachi (OPKC)

After takeoff and climb, the Aircraft cruised at FL370 and the flight proceeded normally.

At 1327:27, the Aircraft commenced its descent, and as it passed 28,300 feet pressure altitude, the flight crew noticed that the cabin altitude was increasing at a rate of about 300 feet per minute.

The flight crew decided to level off at FL270 in order to check if there was any improvement in the cabin altitude. However, no improvement was evident and the cabin altitude continued to increase. The Commander decided to continue the descent.

At 1335:11, the Commander decided to don the flight crew oxygen masks as the cabin pressure was increasing and had almost reached 9,000 feet. At this time, the Aircraft was descending, passing 25,700 feet.

¹ OMAA is the ICAO four letter airport code for Abu Dhabi International Airport

² OPKC is the ICAO four letter airport code for Karachi International Airport



The Commander then commenced an emergency descent by gradually increasing the vertical speed as the Aircraft passed FL250. The Co-pilot informed Karachi area control center (ACC) that EY200 was performing an emergency descent due to cabin pressure failure, and he declared a PAN-PAN³.

As the Aircraft passed through 19,200 feet pressure altitude at 1337:05, an excessive cabin pressure altitude ('EXCESS CAB ALT') warning triggered on the electronic centralized aircraft monitoring (ECAM). At this time, the Aircraft position was about 45 nautical miles west-south west of OPKC.

During the emergency descent, the cabin altitude rose above 10,000 feet, and as the Aircraft was passing approximately 16,400 feet pressure altitude the flight crew decided to deploy the passenger oxygen masks manually. After the deployment of the passenger oxygen masks, the Commander instructed the passengers to use the masks and the cabin crewmembers ensured that all passengers used the masks.

Once the Aircraft was below 10,000 feet pressure altitude, the flight crew removed their oxygen masks.

When the Aircraft was passing 9,580 feet pressure altitude at 1339:38, the Co-pilot informed the ACC controller that EY200 had completed the emergency descent, and he cancelled the PAN-PAN.

At 1340:37, the excessive cabin pressure altitude warning ceased. At this time, the Aircraft had reached 8,000 feet pressure altitude and maintained level at that altitude. The cabin manager was then called and requested by the Commander to check the condition of the passengers and she reported that all the passengers were fine. The Commander then briefed the cabin manager and he advised that the passengers could remove their oxygen masks.

At 1341:22, ATC instructed EY200 to descend to FL070.

At 1342:01, the flight crew set the cabin pressure to 'Manual Mode' as the Aircraft was descending through 7,800 feet pressure altitude, and the Commander provided a NITS⁴ briefing to the cabin manager.

The Aircraft performed an instrument landing system (ILS) approach to runway 25L, and landed uneventfully at 1359:46. The engines were shut down at 1405:53.

1.2 Injuries to Persons

There were no injuries to persons because of the Incident.

Table 1. Injuries to persons					
Injuries	Flight crew	Cabin crew	Passengers	Total onboard	Others
Fatal	0	0	0	0	0
Serious	0	0	0	0	0
Minor	0	0	0	0	0
None	2	4	76	82	0
TOTAL	2	4	76	82	0

³ PAN PAN call is an urgency message, however the situation does not require immediate assistance, and to declare it correctly, the caller repeats it three times: "PAN-PAN, PAN-PAN, PAN-PAN"

⁴ N: Nature of emergency; I: Intention of the captain; T: Time available to brief the passengers and prepare the cabin; and S: Specific instructions (if any)



1.3 Damage to Aircraft

The Aircraft was undamaged.

1.4 Other Damage

There was no damage to property, or to the environment.

1.5 Personnel Information

The qualifications and experience of the Commander and Co-pilot at the time of the Incident were as shown in table 2.

Table 2. Flight crewmembers data

	Commander	Co-pilot
Age	52	27
Type of license	ATPL-A ⁵	MPL
Valid to	3 February 2022	17 June 2025
Rating	M/E LAND, IR/MPA, A320, A340	A320 IR/MPA Restricted to A320 Multi-crew Operations for ETIHAD AIRWAYS co-pilot only
Total flying time (hours)	16,552.75	776.8
Total Command on all types (hours)	1,357.2	Not Applicable
Total on this type	368.08	446.8
Total twelve months (hours)	661.62	446.8
Total on type the last 28 days	29.87	63.47
Total on type the last 14 days	14.93	29.45
Total last 7 days (hours)	14.93	21.88
Total on type last 7 days (hours)	14.93	21.88
Total last 24 hours (hours)	2.07	8.08
Last recurrent SEP ⁶ training	29 October 2017	12 November 2017
Last proficiency check	10 January 2018	13 November 2017
Last line check	5 September 2017	20 September 2017
Medical class	Class 1	Class 1
Valid to	13 October 2018	20 April 2018
Medical limitation	VNL ⁷	Nil
English language proficiency (ELP)	Level 4	Level 6

Based on the flight crew records provided to the Investigation, the flight crew qualifications and experience were not factors in the Incident.

The rosters and other information for both flight crewmembers were reviewed and evaluated and indicated that fatigue was not a factor in the Incident.

⁵ ATPL: Air transport pilot license

⁶ SEP: Safety and emergency procedures

⁷ VNL is a medical limitation code of correction for defective near vision, which means that the licence holder should have readily available spectacles that correct for defective near vision as examined and approved by the aero-medical centre or aero-medical examiners.



1.6 Aircraft Information

1.6.1 Aircraft data

Table 3 illustrates general information related to the Aircraft on the date of the Incident.

Table 3. Aircraft data

Manufacturer:	Airbus
Model:	A320-232
Manufacturer serial number:	3004
Nationality and registration mark:	United Arab Emirates, A6-EIF
Name of the Operator:	Etihad Airways
Certificate of airworthiness	
Number:	EAS/42
Original issue date:	1 April 2012
Re-issue date:	2 May 2013
Valid to:	Airworthiness Review Certificate ARC-EY-EIF-5 13 May 2018
Certificate of registration	
Number:	47/08
Original issue date:	15 May 2008
Re-issue date:	25 December 2014
Valid to:	Open
Date of first flight:	19 December 2006
Time since new (flight hours):	45,169
Cycles since new:	18,859
Last inspection and date:	13 January 2018 (45A Check)
Time since last overhaul (flight hours):	5,363.93
Cycles since last overhaul:	2,259
Maximum take-off weight:	77,000 kg
Maximum landing weight:	66,000 kg
Maximum zero fuel weight:	62,500 Kg

1.6.2 Engine data

Table 4 illustrates general information related to the engines on the date of the Incident.

Table 4. Engine data

Manufacturer:	International Aero Engine	
	No. 1 engine	No. 2 engine
Model:	V2527-A5	V2527-A5
Manufacturer serial number:	V12524	V10361
Date installed on Aircraft:	13 June 2016	2 May 2017
Time since new (hours):	39,861	41,416



Cycles since new:	17,411	26,246
Time since last overhaul (hours):	6,947	4,052
Cycles since last overhaul:	2,906	1,691

1.6.3 Post-Incident inspection

After landing, the following technical defects were reported by the Operator's maintenance:

- Left hand packs duct insulation (*IPC 21-51-03-08A item 63*) was damaged;
- Mixer chamber duct with P/N: D2127774900000, IPC:21-21-02-46B item 50 was leaking;
- All oxygen generators had been used and to be replaced, except six which were not used;
- The right hand air cycle machine anti ice duct was leaking; and
- One safety valve 7HL was inoperative.

1.6.4 Cabin pressurization system

The cabin pressurization system of the A320-232 has four general functions:

- Ground function: Fully opens the outflow valve on the ground;
- Pre-pressurization: During takeoff, increases cabin pressure to avoid a surge in cabin pressure during rotation;
- Pressurization in flight: Adjusts cabin altitude, and rate of change to provide passengers with a comfortable environment;
- Depressurization: After touchdown, gradually releases residual cabin overpressure before the ground function fully opens the outflow valve.

The system consists of:

- Two cabin pressure controllers (CPC);
- One residual pressure control unit (RPCU);
- One outflow valve, with an actuator that incorporates three motors (two for automatic operation, one for manual operation);
- One control panel; and
- Two safety valves.

Normally, one of the two CPCs automatically operates the outflow valve by means of its associated motor.

The flight crew can set the system to operate automatically, semi-automatically, or manually. In normal operation, cabin pressurization is fully automatic.

A schematic of the cabin pressurization system is shown in figure 2.

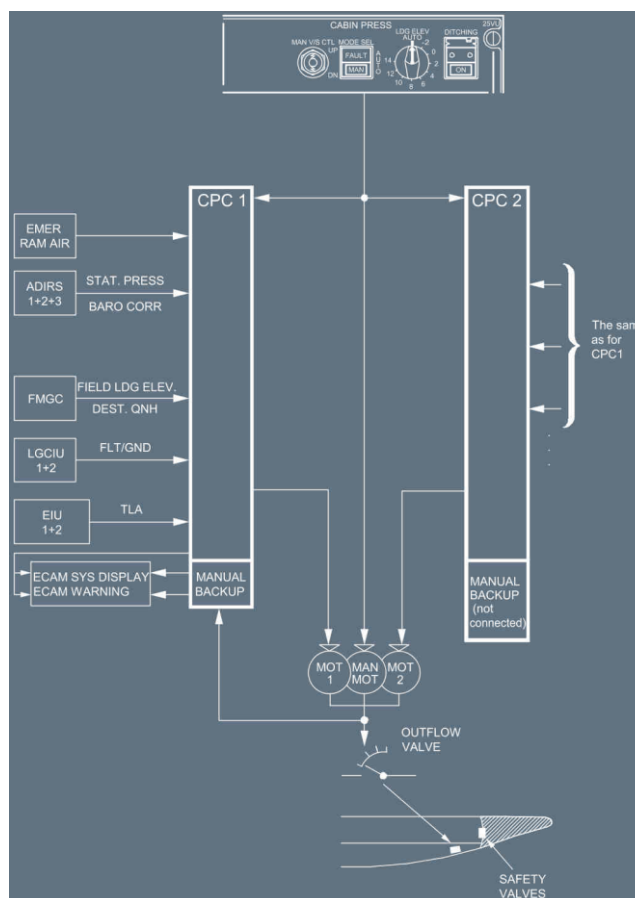


Figure 2. Schematic of cabin pressurization system [Source: Airbus]

1.6.4.1 Automatic operation

In automatic operation, the flight crew monitor the operation of the system. Air pressure in the cabin follows external schedules that the system receives as signals from the flight management and guidance system (FMGS).

When FMGS data is not available for automatic pressurization, the crew need to select the landing field elevation. The pressurization system then uses the manually-selected landing field elevation for internal schedules.

Two identical, independent, automatic systems (each consisting of a controller and its associated motors) control cabin pressure. Either system controls the single outflow valve. Only one controller operates at a time.

An automatic transfer from one automatic system to the other occurs:

- 70 seconds after each landing.
- If the operating system fails.

The controller automatically controls the cabin pressure. It limits the cabin pressure to 8,000 feet maximum and optimizes it during the climb and descent phases.

The controller normally uses the landing elevation, the QNH from the flight management and guidance computer (FMGC), and the pressure altitude from the air data/inertial reference system (ADIRS).

If the FMGC data are not available, the controller uses the captain's BARO reference from the ADIRS and the LDG ELEV selection.

During descent, the controller maintains a cabin rate of descent, such that the cabin pressure is equal to the landing field pressure +0.1 PSI, shortly before landing.

The maximum cabin descent rate is 750 feet/minute.

1.6.4.2 Manual operation

In manual operation mode, the flight crew controls the cabin altitude via the manual motor of the outflow valves, by operating controls on the pressurization control panel.

If both automatic systems fail, the flight crew may use the CABIN PRESS control panel to take manual control of cabin pressurization by the following actions:

- Release the MODE SEL pushbutton to select MAN, and
- Push the MAN V/S CTL switch UP or DN to increase or decrease cabin altitude.

The first of these actions cuts off power to the AUTO motors, and enables the MAN motor to control the outflow valve.

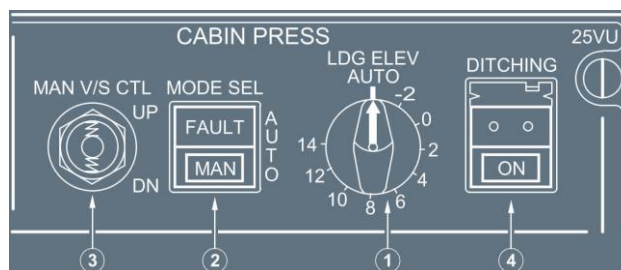


Figure 3. Cabin pressure control panel [Source: Airbus]

Notes for figure 3:

(1) LDG ELEV knob

- AUTO:** The pressurization system uses the FMGS data to construct an optimized pressure schedule. To exit the AUTO position, pull out and turn the selector.
- Other Positions:** The schedule uses the landing elevation selected using the knob (from -2,000 to 14,000 feet as its reference)
- Note:** the LDG ELEV knob scale is only given as an indicator; refer to the ECAM information for accurate adjustment.

(2) MODE SEL pushbutton

- AUTO:** Automatic mode is operating. One of the two systems controls the outflow valve.
- MAN:** This legend appears in white, and FAULT does not come on. The flight crew then uses the MAN V/S CTL selector to control the outflow valve.
- FAULT light:** This legend appears in amber and the ECAM caution light comes on only when both of the automatic systems have failed.
- Note:** 1. Switching the MODE SEL pushbutton to MAN, for at least 10 seconds, then returning it to AUTO will select the other system.

2. The pilot may notice a variation in the CAB ALT indication on the ECAM PRESS page, when the system switches from the cabin pressure control AUTO mode to MAN mode, due to the reduced resolution of the backup pressure sensor.

(3) MAN V/S CTL toggle switch

The switch, which is spring-loaded to neutral, controls the outflow valve position through operation of the MAN motor, when the MODE SEL pushbutton is in the MAN position.

UP: The valve moves towards to the open position

DN: The valve moves towards to the closed position

Note: To target a precise cabin vertical speed rate, only short inputs should be applied on the toggle switch.

(4) DITCHING guarded pushbutton

Normal: The system functions normally

ON: The operating system sends a “close” signal to the outflow valve, emergency ram air inlet, avionics ventilation inlet and extract valves and pack flow control valves.

1.6.4.3 Cabin pressure controllers

Two identical, independent, digital controllers automatically control the system, by maintaining the proper cabin pressure as designed. The controllers receive signals from ADIRS, the FMGC, the engine interface unit (EIU), and the landing gear control interface unit (LGCIU).

When the system is in the automatic or semi-automatic modes, one controller is active, and the other is on standby.

The controllers also generate signals for the ECAM.

For operation in manual mode, each controller has a backup section, which is powered by an independent power supply in the controller No.1 position. This section also has a pressure sensor that generates the cabin altitude and pressure signal for the ECAM, when MAN mode is selected.

The controllers communicate with each other via a cross-channel link.

1.6.4.4 Outflow valve

The outflow valve is on the right-hand side of the fuselage, behind the aft cargo compartment, and below the flotation line.

The outflow valve assembly consists of a flush, skin-mounted, rectangular frame, carrying inward and outward opening flaps linked to the actuator. The actuator contains the drives of the two automatic motors and the manual motor. Either of two automatic motors operates the valve in automatic mode, and the manual motor operates it in manual mode.

In automatic mode, the operating controller signals the position of the valve to the ECAM.

In manual mode, the backup section of the No. 1 controller signals the position of the valve to the ECAM.

1.6.4.5 Safety valve

Two independent pneumatic safety valves prevent the cabin pressure from becoming too high (8.6 psi above the ambient) or too low (1 psi below the ambient).

The valves are located on the aft pressure bulkhead, above the flotation line.

1.6.4.6 Residual pressure control unit (RPCU)

One RPCU automatically depressurize the aircraft in case of abnormal residual pressure when the aircraft is on the ground.

The outflow valve opens automatically , when:

- The outflow valve is not fully open, and
- Both CPCs are failed, or manual mode is selected, and
- The aircraft is on the ground, and
- All engines are shutdown, or all ADIRS indicate an airspeed below 100 knots.

1.6.4.7 ECAM cabin pressure (ECAM CAB PRESS) page

An example of the ECAM cabin pressure page is shown in figure 4.

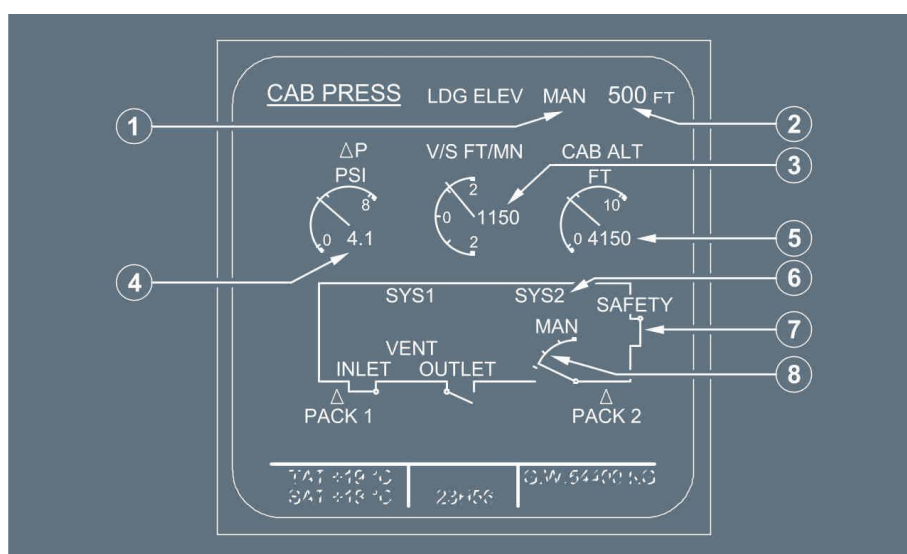


Figure 4. ECAM cabin pressure page [Source: Airbus]

Notes:

(1) LDG ELEV AUTO/MAN

LDG ELEV AUTO: appears in green when the LDG ELEV selector is in AUTO.

LDG ELEV MAN: appears in green when the LDG ELEV selector is not in AUTO.

(2) Landing elevation

The landing elevation selected, either automatically by the FMGS or manually by the pilot, appears in green (but not when the MODE SEL pushbutton switch is in MAN).

(3) V/S FT/MIN (cabin vertical speed)

The analog and digital presentations appear in green when V/S is in the normal range.

(4) ΔP PSI (cabin differential pressure)

The analog and digital presentations appear in green when ΔP is in the normal range. They appear in amber when $\Delta P \leq -0.4$ psi or ≥ 8.5 psi.

(5) CAB ALT FT (cabin altitude)

The analog and digital presentations appear in green, in the normal range. They appear in red if the cabin altitude exceeds 9,550 feet.

(6) Active system indication (SYS 1 or SYS 2 or MAN)

SYS 1 or SYS 2 appears in green when active and in amber when faulty. When either system is inactive, its title does not appear.

MAN appears in green when the MODE SEL switch is in MAN.

(7) Safety valve position

SAFETY appears in white and the diagram in green when both safety valves are fully closed.

SAFETY and the diagram appear in amber when either valve is not closed.

Note: The safety valve opens when the cabin differential pressure is between 8.2 and 8.9 psi.

(8) Outflow valve position

The diagram is green when the valve is operating normally.

The diagram becomes amber when the valve opens more than 95% during flight.

1.6.4.8 Cabin pressure excess warning

The cabin pressure excess (CAB PR EXCESS CAB ALT) warning triggers when:

- In climb or descent, the cabin altitude is above the higher of:
 - 9,550 feet; or
 - 1,000 feet above the airfield pressure altitude
- In cruise, the cabin altitude is above 9,550 feet

1.6.5 Maintenance records

A review of the Aircraft maintenance records for the month prior to the Incident indicated that:

- On 16 January 2018, cabin pressure system 1 was found faulty. The defect was rectified by resetting CPC#1 in accordance with *AMM 24-00-00-810-818a*. A test was carried out in accordance with *AMM 21-31-00-710-002*, and it was found satisfactory.
- On 1 February 2018, a fault was indicated in cabin pressure system 1. OUTFLOW VALVE ELEC 1(78) appeared in the post flight report (PFR). Troubleshooting was performed in accordance with *TSM 21-31-00-810-805*. An operational test of the pressurization control and monitoring system was carried out in accordance with *AMM 21-31-00-710-002*, and no fault was detected.
- On 25 February 2018, the commander of a flight on that day reported that the outflow valve opened suddenly during landing. No fault was found on the PFR. CPC 1 and 2 bite tests were carried out in accordance with *AMM 21-31-00-710-002a*, and were found to be satisfactory.
- An RPCU operational test was carried out in accordance with *AMM 21-31-00-710-802a*, and it was also found satisfactory.

An operational test of the ditching mode was carried out in accordance with



AMM 21-31-00-710-004a, and it was found satisfactory.

An operational test of manual mode was carried out in accordance with AMM 21-31-00-710-003a, and it was found satisfactory.

- On 26 February 2018, the Aircraft had an excessive negative cabin altitude during descent, however, no faults were recorded on the PFR. The cabin altitude was at -2,200 feet as the Aircraft was descending passing 8,000 feet pressure altitude. The cabin altitude was at -3,600 feet as the Aircraft was descending passing 3,800 feet pressure altitude.

Troubleshooting was performed in accordance with TSM 21-31-00-810-827-A. Operational tests of CPC 1 and 2 were carried out in accordance with AMM 21-31-00-710-002, and they were found to be satisfactory. The flight crew were requested to observe the cabin pressurization system further during the next flight and to report anything abnormal.

- On 26 February 2018, cabin differential pressure was found low on short final during a flight on that day. The warning disappeared after several seconds, and no fault was recorded on the PFR. Therefore, no maintenance action was carried out.
- On 26 February 2018, during a different flight, the cabin rate reached more than +3,000 feet per minute, and a hissing sound was heard from door L1. The L1 door seal was inspected in accordance with AMM 52-10-00-220-006A, and no fault was found.

The cabin door fairing was found to be adrift and it was suspected that the fairing became stuck between the seal and the surface. No spare part was available to replace the fairing. Flight crew were requested to observe the cabin rate during the next flight, and to report anything abnormal.

- On 26 February 2018, after landing following a later flight on that day, the cabin altitude indicated 3,000 feet with a differential pressure of 3 psi. The cabin vertical speed rate climbed to 4,000 feet per minute. It was found that a cargo hold thermal blanket was covering the exhaust port of the outflow, which resulted in an airflow restriction. The thermal blanket was secured and an operational test of the cabin pressurization system was carried out in accordance with AMM 21-31-00-710-002, and it was found to be satisfactory.
- On 4 March 2018, on descent, cabin pressure system 1 had an excessive cabin pressure of -3,600 feet until touchdown. Troubleshooting was performed in accordance with TSM 21-31-00-810-809a. It was found that in the last leg the avionic skin air outlet valve was faulty. The valve was replaced in accordance with AMM 21-26-53/PB 401. An operational test of the avionic equipment ventilation was carried out in accordance with AMM 21-26-00-710-001, and it was found satisfactory.

Before the Incident flight, there was one deferred defect of a vent blower fault/avionic skin air inlet valve fault, and a *minimum equipment list (MEL)* item was raised under category C (10 consecutive calendar day). The indicated deferred defect had no relationship to the decompression event during the flight, and it did not have any adverse effect on the flight.

After landing in Karachi, the following maintenance actions were carried out:

- Safety valve 7HL was inoperative and was tagged for further investigation. A new safety valve was required. However, due to unavailability of the spare part, a DDL was raised.



- Due to the cabin pressure excess, outflow valve 10HL was replaced in accordance with *AMM 21-31-51/PB401*.
- Since the cabin vertical speed rose to +300 feet per minute and a cabin pressure excess warning occurred during descent, CPC 1 and 2 were replaced in accordance with *AMM 21-31-34/PB401*. An operational test of manual mode was carried out in accordance with *AMM 21-31-00-710-002*, and was found to be satisfactory for both CPCs. Both CPCs were tagged for further investigation.
- Due to the cabin pressure excess a visual inspection of related air conditioning ducting and mixer unit assemblies in the forward and aft cargo compartments was carried out. No obvious damage was observed during the inspection.
- Visual inspections of pack 1 and 2 bays related to the ducting, bellows, and sleeves was carried out. No abnormalities were found during the inspection.
- Based on the environmental control system (ECS) maintenance report data, the ECS packs flow was normal, and the ECS packs were in normal condition.

The Aircraft was ferried back to Abu Dhabi without passengers after the maintenance actions were carried out.

Following the landing in Abu Dhabi, the following maintenance actions were carried out:

- Safety valve 7HL was found inoperative and was tagged for further investigation. A new safety valve was installed in accordance with *AMM 21-31-52/PB401*.
- The air conditioning pack ducts, trim air ducts, and isolation ducts were checked for cracks and malfunctions in accordance with *TSM 21-31-00-810-809a*.
- Blankets in the vicinity of the outflow valve were inspected and no defects were found. The outflow valve seals were found serviceable in accordance with *AMM 21-31-00-100-001-a*.

A detailed inspection of the plenum chamber of both packs was performed in accordance with *AMM 21-52-00-200-001-a* and no defect was found.

- The left hand pack duct insulation (*IPC 21-51-03-08A item 63*) was found to be damaged. Replacement of the pack duct insulation was required. However, due to unavailability of the spare part a DDL was raised. Three days later replacement of left hand pack duct insulation was carried out in accordance with *AMM 21-52-41/PB401*, and found satisfactory and the DDL was closed.
- On checking for cracks or malfunctions of the air conditioning pack ducts, trim air ducts, and isolation valves, as per *TSM 21-31-00-810-809-A*, the LH pack flow control valve and LH ACM anti-ice duct were found leaking due to seal damage after carrying out leakage check as per *AMM 21-52-00-200-010-A*. The mixer unit duct (*IPC 21-21-46B item 050*) was also found damaged, and therefore it was replaced in accordance with *AMM 21-21-43/PB401*.

1.7 Meteorological Information

The dispatch documents provided to the flight crew included a fixed time prognostic chart of the area of the route from OMAA to OPKC valid for 12:00 UTC, 5 March 2018 from FL100 to FL450. The weather information was forecast about one hour and half before the Incident occurred. However, in that area there was no cumulonimbus clouds at all. Even though the forecast was between 1.5 and 2 hours prior to the flight, the Investigation

considered that the flight did not encounter bad weather at all. There was no evidence from the flight data that the Aircraft experienced any weather issue.

The prevailing meteorological conditions were not a factor in this Incident.

1.8 Aids to Navigation

There were no problems related to ground-based navigation aids, on-board navigation aids, or visual ground aids, or their serviceability in this Incident.

1.9 Communications

All communications between the flight crew and Karachi Tower on 118.3 MHz, Approach on 125.5 MHz, and Ground on 121.6 MHz, were clear and normal.

1.10 Aerodrome Information

Karachi International Airport, ICAO code OPKC, is located 8.5 nautical miles east-north-east of Karachi, Pakistan. The airport elevation is 100 feet. The airport has two concrete runways: 07R/25L with a length of 3,400 meters, and 07L/25R with 3,200 meters length. Runway 25R and 25L are equipped with an ILS CAT I precision approach lighting system.

1.11 Flight Recorders

The Aircraft was equipped with a digital flight data recorder (DFDR) and cockpit voice recorder (CVR) as mentioned in table 5.

Table 5. Flight recorders			
	Type	Part Number	Serial Number
CVR	Honeywell	980-6022-001	120-09462
DFDR	Honeywell	980-4700-042	13382

Data from the DFDR and CVR were successfully downloaded and analyzed. The data provided the Investigation with useful information.

The Investigation also analyzed the quick access recorder (QAR) data since the cabin altitude and cabin differential pressure parameters were recorded by the QAR, but not by the DFDR.

The DFDR, QAR and CVR data were examined, and prior to that, the time between the different recorders was synchronized.

1.12 Wreckage and Impact Information

The Aircraft was intact.

1.13 Medical and Pathological Information

No medical or pathological investigations were conducted because of the Incident, nor were they required.

1.14 Fire

There was no sign of fire.

1.15 Survival Aspects

None of the persons on-board sustained any injury. The Passengers and crew disembarked normally at Karachi International Airport.



1.16 Tests and Research

1.16.1 Laboratory testing of the related components of the cabin pressure system

Two cabin pressure controllers, one outflow valve, and one safety valve were shipped to the manufacturer (Nord-Micro) for examination. The details of the components were as shown in table 6.

Table 6. Examined components				
Component	Part Number	Serial Number	Flight Hours	Manufacture Date
Cabin Pressure Controller (CPC1)	20791-02AB	0354837	59,802	November 2003
Cabin Pressure Controller (CPC2)	20791-03AB	0854650	35,432	July 2008
Outflow Valve (OFV)	20790-03AC Amdt. AB	0951649	27,583	February 2009
Safety Valve (SV)	9024-15704-2 Amdt. AB	0672398	45,169	October 2006

The original equipment manufacturer (OEM) provided a report on the testing and examination of the components.

The testing and examination provided the following information.

Two warnings/maintenance status messages were found on the PFR. These were 'CAB PR EXCESS CAB ALT' at 1337, and 'CAB PR SAFETY VALVE OPEN (2)' at 1340.

Two other messages relating to the Incident were also found as ECAM messages. These were 'CAB PR LO DIFF PR' at 1338 and 'CAB PR SAFETY VALVE OPEN' at 1340.

From the non-volatile memory (NVM) data of CPC1, it was found that the classic buffer and the fixed buffer had no entries directly related to the event.

From the non-volatile memory data of CPC2, it was found that the classic buffer had no entries directly related to the event. The last entry of the fixed buffer listed a 'Fault code 96', which related to excessive cabin altitude.

From the laboratory testing, all component functional tests were passed, despite some minor findings.

1.16.1.1 Safety valve

Due to heavy contamination, typical for the age of the safety valve, the visual inspection failed, however, the functional tests were passed. After rework of the findings, the safety valve passed the acceptance test in accordance with the *component maintenance manual (CMM)*. The shop's findings were:

- Filter and controller polluted;
- Diaphragm warped;
- Switch oxidation;
- Bonding strap repainted.

1.16.1.2 Cabin pressure controller, CPC1

During the visual inspection of CPC1, heavy contamination of capacitors 1803 and 1804 was found. The mainboard was heavily covered in dust. Leaking and corrosion marks

were visible on the ARINC⁸ plug and the pins of the transducer board (figure 5). The unit had been in service for about 5 years and 4 months, which explained the level of contamination. An NVM readout was performed.



Figure 5. CPC1 transduced boards

1.16.1.3 Cabin pressure controller, CPC2

CPC2 passed the functional test with the exception of the bonding resistance test. The bonding resistance value was out of tolerance; however, the failed bonding resistance test had no effect on the Incident. The unit had been in service for about 4 months and had minor faults during shop visits after the Incident.

From the non-volatile memory readout, Fault Code 96 was indicated which related to excessive cabin altitude. As a preventive action, RAM ICs 702 and 703 were re-soldered. After the rework, the CPC2 passed the acceptance test in accordance with the *CMM*.

1.16.1.4 Outflow valve

It was revealed that electronic box 1 (E-Box 1) had a damaged cover, and the connector J3 was in a bent condition (figure 6). Despite these findings, the outflow valve passed the functional test in accordance with the *CMM*. Both electronic boxes also passed the functional test in accordance with the *CMM*.



Figure 6. Outflow valve – E-box 1 with damaged cover and bent connector J3

Load tests of the gearbox were performed, and the gearbox passed the test sequence.

1.16.2 System behavior findings

The triggering of the cabin pressure excess warning was characterized by a slow decompression, at about 300 to 400 feet per minute cabin pressure climb rate, as shown in table 7. The excessive cabin altitude ('EXCESS CABIN ALT') warning was triggered by CPC2 when the cabin altitude was increasing through 9,536 feet at 1337:03.

⁸ ARINC: Aeronautical Radio, Incorporated



Table 7. ECS data summary

UTC	Altitude [feet]	Cabin Altitude [feet]	Airfield Level [feet]	Cabin pressure Rate [ft per min]	Differential Pressure [psi]	Outflow Valve [%]	Pressure Controller Status Word	CPC
1334:18	27,139	8,464	96	300	5.8	8	1501	1
1334:33	27,031							
1334:48	26,442	8,656	96	300	5.5	8	1501	1
1335:03	26,022							
1335:18	25,469	8,848	96	300	5.2	9	1501	1
1335:33	24,850			400	5.0	9	1501	1
1335:48	24,142	9,040	96	300	4.8	9	1501	1
1336:03	23,122	9,152	96	400	4.5	7	1501	1
1336:18	22,059			400	4.2	9	1501	1
1335:33	21,116	9,344	96	300	3.9	10	1501	1
1336:48	20,254	9,152	96	400	3.6	10	1501	1
1337:03	19,454	9,536	96	300	3.3	10	1501	1

As shown in table 7, the differential pressure (between the cabin altitude and Aircraft pressure altitude) was decreasing. The outflow valve was stable at between 8 and 10%. CPC1 was the system in control prior to and during the warning.

1.16.3 Fault entries description

1.16.3.1 Excessive cabin altitude warning

The EXCESSIVE CABIN ALTITUDE warning was triggered by CPC2, while CPC1 was the system in control prior and during the warning.

The cabin altitude/pressure rate was between 300 and 400 feet per minute.

The airfield elevation was 96 feet. This was correct for the airfield elevation of Karachi airport (OPKC).

The pressure control status word (PCSW) had a value of 1501, which means that CPC1 was the system in control prior to and during the warning, but CPC1 did not trigger the warning. The flight mode of CPC1 was 'Descent Internal' while the landing field elevation selector (LFES) was in 'Auto'.

The CPC should provide an output of excessive cabin altitude ('EXCESS CABIN ALT') warning, when the cabin pressure is below a critical value, depending on the flight mode, flight level, and landing field altitude. The critical value is calculated by the CPC and is limited to a range of between 8.46 and 10.28 psi. The cabin pressure of 10.28 corresponds to a cabin altitude of 9,550 feet.

For high altitude landing operations, there is a suppression logic, so that the excessive cabin altitude warning during climb and descent is shifted if the landing altitude is higher than 9,550 feet.

As there is an 'OR' condition in the ECAM logic, the warning is displayed in the cockpit if CPC1 or CPC2 generates the warning, regardless of the system in control.



1.16.3.2 Low differential pressure warning

Low differential pressure warning will be set and provided to the crew via ECAM if the aircraft is about to overrun the cabin altitude due to the rapid descent. Hence, the low differential pressure warning can only be set in the descent mode.

1.16.3.3 Cabin pressure safety valve open

The safety valve limits the differential pressure of the cabin pressure relative to the ambient pressure in order to protect the fuselage. The safety valve operates in both directions responding to overpressure from the aircraft cabin pressure to the ambient pressure (positive differential pressure) and vice versa overpressure from the ambient pressure to the aircraft cabin pressure (negative differential pressure).

If a specified differential cabin pressure is reached, the safety valve will release the exceeding overpressure. If the safety valve stays open for at least 60 seconds, a display in the cockpit will indicate that the safety valve has opened.

In this Incident, the PFR showed 'CAB PR SAFETY VALVE OPEN (2)' at 1340. That means the safety valve opened for the first time at 1339. After staying open for (at least) 60 seconds, the warning was triggered at 1340. The '... (2)' indicates that the safety valve reacted to the overpressure condition twice. Only the time of the first opening of the safety valve was recorded in the PFR, while the subsequent openings of the valve were derived from the number in brackets, but they could not be attributed to precise times.

1.16.4 Root cause

As mentioned in sub-section 1.16.1, the proceeding analysis of the data and fault entries indicate that the outflow valve and the safety valve can be excluded as the cause of the occurrence, since no malfunction of either valve was proven.

CPC2 could also be excluded based on the findings as mentioned in sub-section 1.16.1 and 1.16.2. The 'EXCESS CABIN ALT' warning was triggered by CPC2, and CPC2 was the only CPC to have the relevant data recorded in non-volatile data. Therefore, it can reasonably be concluded that CPC2 functioned as designed in standby mode.

The summary of the events leads to the following:

- The Aircraft was in a descent when the flight crew noticed the cabin altitude was increasing.
- CPC1 was the system in control.
- CPC2 triggered an excessive cabin altitude warning when the cabin altitude reached 9,550 feet.
- CPC1 did not trigger any warnings while controlling the cabin pressure towards higher altitudes with a cabin vertical rate of 300 to 400 feet per minute.
- CPC1 was in flight mode 'Descent internal'.
- The landing field elevation was set correctly to 96 feet.
- Since CPC1 did not consider itself as erroneous, therefore, CPC1 did not transfer control to CPC2.

As the Aircraft was in descent, the expected task to be performed by the CPC in control was to regulate the cabin altitude towards the landing field elevation.

From the evidence stated above, the CPC in control (CPC1) performed correctly. The given indications inferred that CPC1 performed the 'normal' operations of cabin pressure control for a high elevation landing field.



The cabin altitude rate of 300 to 400 feet per minute was well within the defined rate limits for the descent internal (DI) mode for high altitude operation. These limits were +250 to +750 feet per minute.

As indicated by the data, CPC1 was in control and the cabin altitude rate and the outflow valve position were quite stable and appropriate for the controlled decompression rate. However, the landing field elevation of 96 feet did not fit the 'normal' value for a high elevation landing field. This means that although the landing field elevation was adjusted correctly, CPC1 did not use the correct value to regulate the cabin altitude towards the scheduled landing field elevation of 96 feet. CPC1 must have used a corrupt value, which led it to regulate the cabin altitude towards a high landing field. Therefore, it is likely that the root cause of this event was within the control mechanism of CPC1.

1.16.4.1 Corrupted memory mechanism

A fault in the range of the landing field elevation input, which is provided either by a message from the FMS, or by the landing field elevation system (LFES analog signal) was excluded. This exclusion was because with such a fault, the discrepancy between the displayed landing altitude and the operational landing altitude could not be explained. Apart from that, CPC1 did not show any fault at the laboratory testing.

Therefore, the search of the root cause was concentrated on a corrupted memory mechanism, which could lead to a corruption of the landing pressure.

The examination focused especially on moving average filters⁹. This approach was because in this controller, the chosen software implementation of moving average filters was vulnerable to bit corruption in the memory, with a potential effect that could persist over infinite time. One of the identified moving average filters was implemented in the scheduled landing pressure logic.

A bit corruption of the scheduled landing pressure has a visible effect only in the descent mode, as reported by the OEM.

Nevertheless, the bit corruption could take place before, in the cruise mode, which would not have a visible effect. The effect will remain dormant until the CPCS switches to descent mode. The bit corruption remains present until the next reset of the controller. This means that a corrupted memory impact while a controller is in standby state during one flight may not become visible until the switch to descent mode is set in the subsequent flight where that controller is in the operational state.

The above-mentioned system behavior was detected using an analytical approach that had been verified in the earlier hardware in the loop system tests. A faulty state change in the SUM software parameter was entered into the CPC in descent mode, and the expected behavior could be proven (figure 7).

⁹ The moving average filter is a simple Low Pass FIR (Finite Impulse Response) filter commonly used for smoothing an array of sampled data/signal.

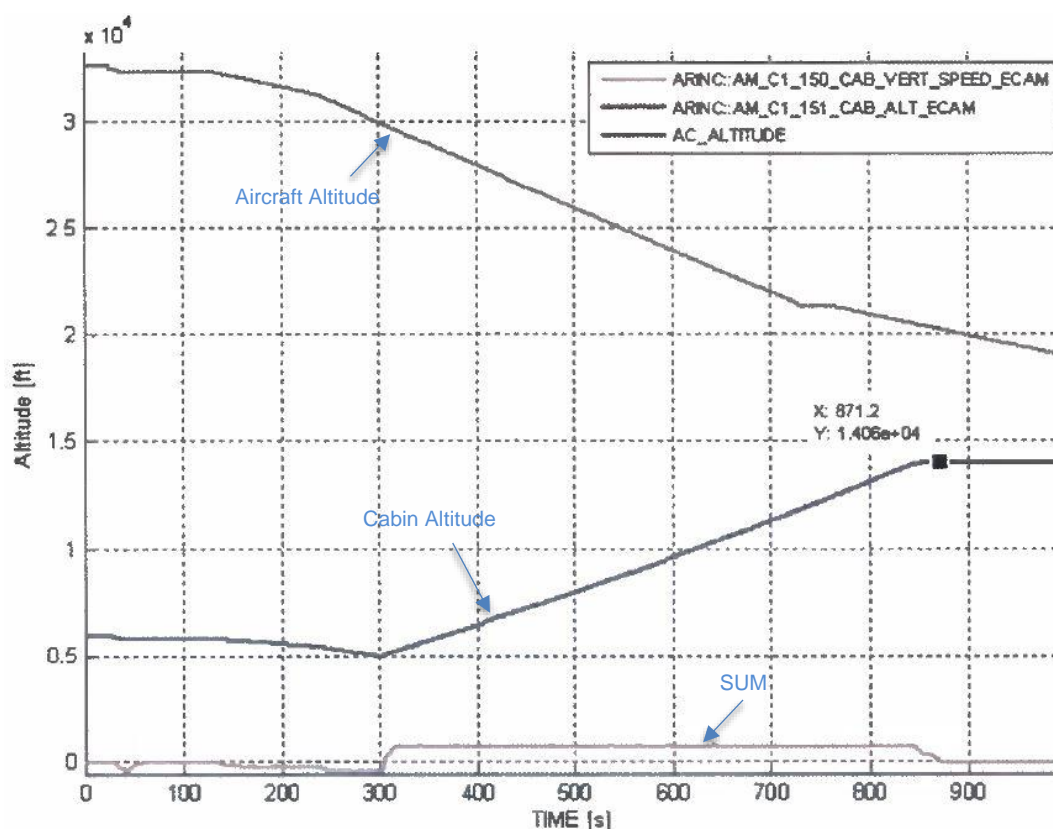


Figure 7. Hardware in the loop system test – faulty state change

As shown in figure 7, at the time of 140 seconds, descent mode was commenced by the CPC, and the cabin altitude commenced to pressurize towards a landing field elevation of 1,000 feet.

At 300 seconds, a bit flip of the SUM value was simulated¹⁰ (see Sub-section 1.16.4.2). This simulation affected the target pressure of the scheduled landing pressure used in the descent mode.

Due to the corrupted scheduled landing pressure, the cabin altitude started to rise at a constant rate. The depressurization stopped when the cabin altitude reached 14,000 feet, which was the internal software limit for the scheduled landing pressure.

The landing field elevation indicated to the ECAM constantly remained at 1,000 feet, and the excessive cabin altitude warning was not triggered due to the shifting of the warning set point according to the scheduled landing pressure.

From the simulation, it was shown that:

- The CPC software contained a filter, which was sensitive to a bit corruption in the memory, and a faulty state change of a bit in this filter could lead to the event scenario.
- The landing field elevation value that was sent to the ECAM and recorded in the non-volatile memory, was different from the corrupted landing pressure value, which was used for cabin pressure control.
- With this scenario, an excessive cabin altitude ('EXCESS CAB ALT') warning was not triggered, because the corrupted landing altitude value was also used

¹⁰ Single event upset (SEU) fault injection mechanism simulates the SEU effects in memory related components (single flip-flops or latches, registers and memories) provoking bit flips into them.

for this warning logic and the triggering was suppressed. Therefore, the non-volatile memory of the CPC did not show this event.

Based on this result, the OEM performed a long-term (3 days) test with the purpose of monitoring the SUM parameter. CPC1 was attached to a tester to simulate the Incident in-flight conditions. CPC1 was in operational state and kept working for 3 days. However, in the given conditions, a bit-flip of the SUM value could not be observed. Consequently, the question arose as to what would cause a bit-flip to occur during the Incident flight?

1.16.4.2 Single event upset

A single event upset (SEU) is defined as a bit-flip in a memory cell of a digital electronic device. At high altitudes, a naturally occurring phenomenon called cosmic radiation, which contains high-energy particles can affect the status of memory cells when they are struck by such a particle. Therefore, an SEU (bit-flip) may be caused by a high energy nuclear particle strike. An SEU is also defined as a bit-flip that recovers at the next writing cycle of the software code.

A single event latch-up (SEL) is defined as a bit-flip, which does not recover at the next cycle of the software code. The SEL events have a much lower statistical frequency than the SEUs.

It could be shown by analysis that SEU events could lead to a permanent offset of some parameters in the involved CPC. Such behavior is caused by moving average filters in the software code. The special coding of these filters in the CPC software allow that one single bit-flip in a memory cell leads to a permanent offset. This offset will only recover at the re-initialization of the filter. This recovery only happens by a hard reset (power reset).

The flow diagram (figure 8) illustrates the software code of the moving average filters, which were implemented in the CPC software. This type of moving average filter was applied for the calculation of the scheduled landing pressure.

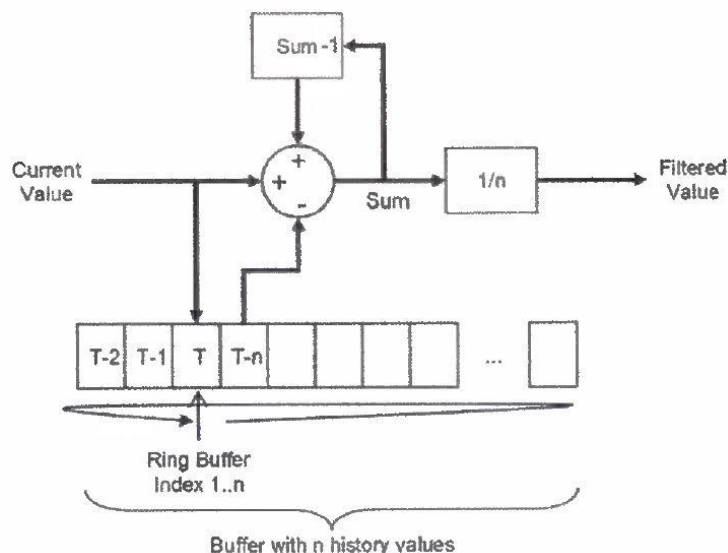


Figure 8. Flow diagram of moving average filter

If a bit-flip, as a result of an SEU, or an intermittent digital failure (see sub-section 1.16.4.3), occurs in one of the memory cells of the value for $T \dots T-n$, or at $\text{Sum}-1$, then this offset will be continuously active until the filter is re-initialized.

1.16.4.3 Intermittent digital failure

The same effect as an SEU can also be caused by intermittent digital failure (IDF).

Some cases of cabin pressurization events in the past were traced back to erroneous data caused by fatigue in soldered joints, due to aging effects.

As the calculation of the scheduled landing pressure was located in the memory (RAM IC702 and IC703), the in-service experience with A320 CPCs (part number 20791-xyxy) showed that re-soldering of IC702 and IC703 could solve this problem.

1.17 Organizational and Management Information

1.17.1 General information

The Operator commenced operations in November 2003 under an air operator certificate (AOC) issued by the General Civil Aviation Authority of the United Arab Emirates.

1.17.2 Training

All required training for the Operator's pilots was described in Part D of the *Operations Manual*.

Rapid depressurization and conducting an emergency descent were included in the Operator's A320 Initial Training, Type Rating, Line Training, and Recurrent Training. The subject training was also included in the full flight simulator (FFS) and Airbus procedures training (APT).

1.17.3 Procedures

1.17.3.1 Quick reference handbook (QRH) cabin overpressure abnormal and emergency procedures

The following procedure shall be applied in case of total loss of cabin pressure control leading to overpressure.

PACK 1 OR 2.....	OFF
VENTILATION BLOWER.....	OVRD
VENTILATION EXTRACT.....	OVRD
<i>Cabin air is extracted overboard</i>	
ΔP	FREQUENTLY MONITOR
● If $\Delta P > 9$ PSI:	
LAND ASAP	
PACK 1.....	OFF
PACK 2.....	OFF
● 10 min before landing:	
PACK 1.....	OFF
PACK 2.....	OFF
VENTILATION BLOWER.....	AUTO
VENTILATION EXTRACT.....	AUTO
● Before door opening: CHECK ΔP ZERO	

Figure 9. QRH cabin overpressure abnormal and emergency procedures

1.17.3.2 Cabin pressure excess warning

The following *flight crew operating manual (FCOM)* procedure shall be applied when a CAB PR EXCESS CAB ALT warning is triggered.



- If above FL 100:
CREW OXY MASK.....USE
- If below FL 160:
DESCENT.....INITIATE
MAX FL.....100/MEA
- If above FL 160:
SIGNS..... ON
EMER DESCENT:
DESCENT..... INITIATE
 - If A/THR is not active:
THR LEVERS.....IDLE
If the A/THR is active, check A/THR is at IDLE on the ED.
- L2 SPD BRK..... FULL
Extension of speedbrakes will significantly increase VLS.
In order to avoid autopilot disconnection and automatic retraction of speedbrakes due to possible activation of angle of attack protection, allow the speed to increase before starting to use speedbrakes.
- L1 SPD..... MAX/APPROPRIATE
- L2 Descend at maximum appropriate speed. However, if structural damage is suspected use the flight controls with care and reduce speed as appropriate. The landing gear may be extended. In this case, speed must be reduced to VLO/VLE.
- L1 ENG MODE SEL.....IGN
ATC.....NOTIFY
- L2 Notify ATC of the nature of the emergency, and state intention. The flight crew can communicate with the ATC using voice, or CPDLC when the voice contact cannot be established or has a poor quality.
Squawk 7700 unless otherwise specified by ATC.
- L12 Note: To save oxygen, set the oxygen diluter selector to N position.
With the oxygen diluter left to 100 %, oxygen quantity may not be sufficient for the entire descent profile.
Ensure that the flight crew can communicate wearing oxygen masks. Avoid the continuous use of the interphone position to minimize the interference from the noise of the oxygen mask.
- L1 MAX FL.....100/MEA
- IF CAB ALT > 14 000 FT:
PAX OXY MASKS.....MAN ON
- L2 This action confirms that the passenger oxygen masks are released.
Note: When descent is established and if time permits, check that the OUTFLOW VALVE is closed on the CAB PRESS SD page. If it is not closed and ΔP is positive, select the other CPC. If the OUTFLOW VALVE is still not closing set the cabin pressure MODE SEL pb to MAN and the V/S CTL sw to full down.
Notify the cabin crew when the aircraft reaches a safe flight level, and when cabin oxygen is no longer necessary.

dent.: PRO-ABN-CAB_PR-T-00010755.0001001 / 05 AUG 10

STATUS

MAX FL.....100/MEA

Figure 10. FCOM procedure for CAB PR EXCESS CAB ALT warning



1.18 Additional Information

There was no other factual information which was relevant to the circumstances of the Incident.

1.19 Useful or Effective Investigation Techniques

This Investigation was conducted in accordance with Part VI, Chapter 3 of the United Arab Emirates *Civil Aviation Regulations*, and the AAIS approved policies and procedures, and in conformity with the Standards and Recommended practices of *Annex 13 to the Chicago Convention*.

2. Analysis

2.1 General

The Investigation collected data from various sources for the purpose of determining the causes and contributing factors that led to the Incident.

This analysis covers cabin pressurization system issues, related Operator's procedures, and flight operations.

This part of the Report explains the contribution of the relevant aspects to the Incident. The analysis also contains safety issues that may not be contributory to the Incident but are significant in adversely affecting safety.

2.2 The Flight

Before the top of descent at FL370, the flight crew went through the descent preparation as per the *flight crew operating manual (FCOM)*. The Commander briefed the passengers that the Aircraft would start to descend within five minutes.

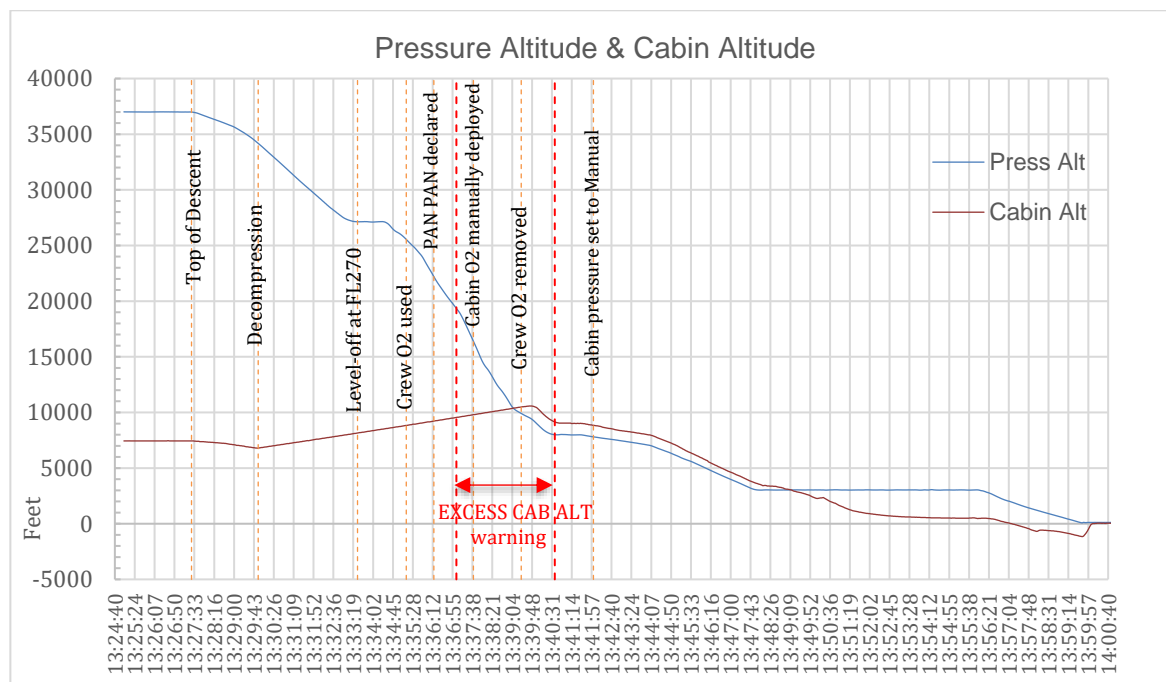


Figure 11. Aircraft pressure altitude and cabin altitude

The Co-pilot contacted ATC and requested a clearance to descend. ATC provided a clearance to descend to FL150.

The cabin altitude started to increase as the Aircraft was descending through 34,200 feet pressure altitude. The Co-pilot questioned whether the cabin vertical speed was normal when the Aircraft was passing through 28,350 feet pressure altitude. Then, the CAB PRESS page in the electronic centralized aircraft monitoring (ECAM) was selected which provided precise information on the cabin pressurization system to the flight crew. It indicated that the cabin vertical speed was increasing instead of decreasing. This was discussed and agreed by the flight crew, and they decided to reduce the cabin vertical rate manually.

As the Aircraft was descending through 27,350 feet pressure altitude, the Co-pilot mentioned that the cabin altitude was now at 8,000 feet. At this moment, both flight crewmembers realized that there was a problem with the cabin pressurization system. Therefore, the flight crew contacted ATC and requested to maintain the Aircraft at FL270. The



intention was to have sufficient time for both flight crewmembers to understand the problem, see if there was any improvement, make any appropriate decisions, and then take corrective action.

While the Aircraft was maintaining FL270 both flight crewmembers realized that the cabin altitude was still continuing to increase. The Commander then decided to descend the Aircraft, and 'open descent' mode was set.

As the Aircraft started to descend from FL270, the flight crew discussed the need to don the oxygen masks since there was no improvement in cabin altitude, instead it continued to increase. However, the Commander preferred to wait for a while to monitor further progress on the issue.

The Commander decided to don the oxygen masks when the cabin pressure had almost reached 9,000 feet, which was agreed by the Co-pilot, and the Aircraft was descending through 25,700 feet. The cabin differential pressure was about 5.3 psi. The Co-pilot then informed the Approach controller that the Aircraft would continue to descend to FL150.

The flight crew donned their oxygen masks as the Aircraft was descending through 25,550 feet pressure altitude. At this time, the cabin altitude had almost reached 9,000 feet and continued to increase. The flight crew encountered no internal communication problems while the oxygen masks were in use. The rapid descent was performed by increasing the descent vertical speed gradually from -2,400 down to -5,900 feet per minute.

As the Aircraft was descending and passing 23,000 feet pressure altitude, the Commander made a passenger address about performing an emergency descent. The Co-pilot then informed Karachi Approach that they were performing an emergency descent due to a cabin pressure failure. They declared a PAN PAN and ATC cleared the Aircraft to descend to FL110.

As the Aircraft was passing approximately 19,350 feet pressure altitude, the cabin pressure excess warning triggered in the cockpit. This was also recorded in the maintenance PFR. The cabin pressure excess warning triggered when the cabin altitude reached 9,536 feet, which was close to the designed 9,550 feet triggering point. There was a delay of the warning triggering in the cockpit, approximately one to two seconds compared to the environmental control system (ECS) maintenance report obtained from the centralized maintenance system (CMS). According to the ECS maintenance report, the warning triggered when the Aircraft was passing approximately 19,450 feet pressure altitude.

The flight crew then performed the *FCOM* procedure for cabin pressure excess correctly. At the end of the procedure, the passenger oxygen masks were deployed manually as the Aircraft was descending passing about 16,400 feet pressure altitude, while the cabin altitude was increasing through 9,800 feet. The Commander then advised the passengers over the passenger address that the Aircraft was performing an emergency descent, and instructed the passengers to use the deployed oxygen masks immediately. Thereafter, the cabin crewmembers ensured that all passengers used the masks.

As per design, the passenger oxygen masks would have deployed automatically when the cabin altitude exceeded 14,000 feet since the 'HI ALT LANDING' pushbutton switch was in the OFF position. However, in this Incident, the passenger oxygen masks were manually deployed by opening the switch guard and pushing the 'MASK MAN ON' button, when the cabin pressure altitude was still far below 14,000 feet (the actual cabin altitude was 9,800 feet).

Both flight crew stated that the cabin altitude rose rapidly after it reached 10,000 feet, and they believed that the cabin altitude would have obviously reached 14,000 feet soon. Hence, the decision to deploy the passenger oxygen masks manually was made by the Commander in order to prevent any risk to the passengers. However, the passenger oxygen



masks were deployed when the cabin altitude was increasing through 9,800 feet (still below 10,000 feet).

The Aircraft pressure altitude and the cabin altitude had the same pressure when the Aircraft was descending through 10,380 feet, and thereafter the cabin differential pressure became negative.

The maximum cabin altitude was 10,576 feet as the Aircraft descended through approximately 9,500 feet pressure altitude. After the maximum value was reached, the cabin altitude decreased continuously following the descent altitude of the Aircraft.

According to the *FCOM* procedure, the passenger oxygen masks should be manually deployed if the cabin altitude is above 14,000 feet and in case the automatic deployment does not work. The incremental increase of the cabin altitude rate was constant, about 385 feet per minute. With this rate of increment, the 14,000 feet cabin pressure altitude would have occurred approximately 10 minutes and 53 seconds after the manual deployment of the passenger oxygen masks.

The Aircraft emergency descent rate was approximately 3,840 feet per minute, and therefore only one minute and 40 seconds elapsed during the descent from 16,400 feet to 10,000 feet pressure altitude.

The Investigation believes that the manual deployment of the passenger oxygen masks was a precautionary action by the flight crew. The *FCOM* cabin pressure excess procedure was performed by the flight crew in line with the SOP, except for the early deployment of the passenger oxygen masks. For the reasons stated above the Investigation believes that the manual deployment of the passenger masks was not necessary.

Therefore, the Investigation recommends that the Operator promulgate details of this Incident to all flight crewmembers and include appropriate aspects of the Incident in flight crew training. In particular, the action of the flight crew, which was not in accordance with the SOP, in manually deploying the oxygen masks should be referred to in the distributed information and training.

Both flight crewmembers removed their oxygen masks just after the Aircraft reached 10,000 feet pressure altitude and continued descending. They informed ATC that the emergency descent was completed and the PAN-PAN was cancelled.

The minimum cabin differential pressure reached -0.59 psi when the Aircraft was descending between 9,000 feet and 8,500 feet pressure altitude.

When the Aircraft just reached 8,000 feet pressure altitude and maintained at that level, the excessive cabin pressure warning disappeared with a cabin altitude of about 9,200 feet. This means that the excessive cabin pressure warning triggered for about three minutes and 30 seconds. The Commander then briefed the cabin manager that the passengers could remove their oxygen masks since the Aircraft altitude was low and safe.

The flight crew set the cabin pressure to 'Manual Mode' when the Aircraft was descending passing 7,800 feet pressure altitude. The Commander then provided a NITS briefing to the cabin manager.

As the Aircraft was passing 7,430 feet pressure altitude, the Commander asked the Co-pilot for the 'Aircraft status', during which they reviewed the setting of the manual cabin pressure mode including the minimum target cabin pressure, and the descent rate of the cabin altitude. They also briefed the approach procedures, for runway 25L.

The Investigation could not determine the setting of the manual cabin vertical speed and the minimum cabin altitude since they were not recorded by either the DFDR or the QAR.

As the Aircraft descended through 7,100 feet pressure altitude, ATC instructed the flight crew to descend and maintain to FL50.

As the Aircraft was passing 6,270 feet pressure altitude, the Commander mentioned that the cabin altitude was decreasing, and the Co-pilot mentioned that the cabin vertical speed target should be 300 feet per minute. The Commander then mentioned that the cabin altitude needed to be lowered as much as possible.

The Commander requested the Co-pilot to brief the approach checklist, which was performed correctly as per the *FCOM* as the Aircraft was descending through 6,000 feet pressure altitude.

ATC instructed the flight crew to descend the Aircraft to 3,000 feet, and provided the 1012 mbar QNH as the Aircraft was passing 5,750 feet pressure altitude. The selected altitude was set to 3,000 feet. The approach briefing then continued. The decision height was set to 318 feet.

The Commander mentioned that the cabin altitude was decreasing towards 5,000 feet, as the Aircraft was descending passing 4,440 feet pressure altitude. At this point, the cabin differential pressure was maintaining at -0.34 psi.

When the Aircraft reached 3,000 feet pressure altitude and maintained that level, the Commander asked ATC Approach if they could stay a bit longer on downwind in order to reduce the cabin pressure manually. This was approved by the Controller.

At 1349:00, the cabin altitude was descending through 3,000 feet as mentioned by the Co-pilot. About 27 seconds later, the cabin altitude was descending through 2,600 feet, while the Aircraft was still maintaining level at 3,000 feet pressure altitude.

The flight crew were trying to return the cabin pressurization system to automatic mode, and this resulted into an increased cabin altitude, which was still abnormal. Hence, it was reset to manual mode to lower the cabin altitude. The Co-pilot mentioned that he would keep lowering the cabin altitude until it reached zero feet.

The Aircraft turned left onto 340 degrees to the base leg while maintaining level at 3,000 feet pressure altitude, and later ATC Approach instructed the flight crew to turn left when ready onto a heading of 280 degrees for an ILS approach to runway 25L.

The cabin altitude was descending through 900 feet at 1352:41, while the Aircraft was maintaining 3,000 feet pressure altitude.

About 30 seconds later, the Co-pilot informed ATC Approach that the Aircraft was established on the localizer, as it was turning left through 270 degrees and the Controller instructed the crew to continue the ILS approach to runway 25L.

The glideslope was alive when the Aircraft was at 11 nautical miles DME, while maintaining level at 3,000 feet pressure altitude on 253 degrees heading. As the Aircraft was maintaining level at 3,000 feet the cabin altitude descended from 3,500 feet to 480 feet.

The Commander requested the Co-pilot to go through the landing checklist, which was performed by the flight crew when the Aircraft was at six DME.

The Aircraft landed uneventfully at 1359:46.

Except the manual deployment of the passenger oxygen masks, both flight crewmembers operated the flight in accordance with the Operator's *standard operating procedures (SOP)*. They carried out all necessary checklists, including the abnormal and emergency procedures for cabin pressurization.

The external and internal cockpit communications were conducted in accordance with the Operator's procedures. The flight crew did not exhibit any confusion or uncertainty



after the occurrence of the cabin pressure issue, or during the required actions and procedures that needed to be taken.

The Commander was the pilot flying, however, more than once, he transferred control to the Co-pilot when he communicated with ATC, and the cabin crew. These were performed as considered necessary by the Commander. Nevertheless, high alertness and good situational awareness were maintained by both flight crewmembers at all times.

2.3 Cabin Depressurization

Maintenance records provided to the Investigation revealed that the Aircraft had repetitive cabin pressurization system faults and failures during the six weeks prior to the Incident. Troubleshooting, rectifications, and operational tests were performed in accordance with the *troubleshooting manual (TSM)* and *aircraft maintenance manual (AMM)*, and all tests were found satisfactory.

On the previous flight, one day before the Incident, there was a cabin pressurization defect. Cabin pressure system 1 had an excessive cabin pressure during descent until touchdown. However, troubleshooting was carried out according to the *TSM* with a satisfactory result, and the Aircraft was released for flight.

After the Incident, both cabin pressure controllers, the outflow valve, and one safety valve were shipped to the manufacturer for further examination. This revealed that the maintenance actions taken in the last six weeks prior to the Incident by the Operator could not identify the root cause of the cabin pressurization issues.

The examinations were performed by the cabin pressure system manufacturer based on the required functional tests and analysis of the non-volatile memory (NVM) data of the CPCs, in combination with other relevant data recorded by the flight data recorder and quick access recorder (QAR) during the Incident flight.

According to the cabin pressure system manufacturer's report, CPC2, the outflow valve, and the safety valve passed all required functional and acceptance tests.

CPC1 was the system in control; however, it did not trigger any warnings while controlling the cabin towards higher altitudes with a cabin vertical rate of 300 to 400 feet per minute. CPC1 was in 'flight' mode 'descent internal'.

CPC1 did not consider itself as erroneous, therefore it did not transfer control to CPC2.

CPC2 triggered the excessive cabin altitude warning when the cabin altitude reached 9,536 feet. The landing field elevation was 96 feet, which was about the same as OPRC airport elevation.

CPC1 was in control of the cabin pressurization system and it regulated the cabin altitude towards the landing field elevation. However, CPC1 performed 'normal' operation of pressure control for a high landing field elevation. The cabin altitude rate of 300 to 400 feet per minute and the outflow valve function were found fit and stable for the controlled decompression rate. Even though the landing field elevation was adjusted correctly to the OPRC airport elevation, CPC1 did not use this correct value to regulate the cabin altitude towards the scheduled landing field elevation of 96 feet. Instead, it most probably used a corrupt value that led it to regulate the cabin altitude towards a high landing field elevation.

Because of the events described previously, the Aircraft experienced a slow cabin depressurization during the descent from FL370.

The corrupt landing field elevation value was caused, most probably, by a bit corruption in the memory cell of the digital electronic system of CPC1. It was shown by the OEM analysis and the system test that there was a software filter that was sensitive to the

corrupted memory effects. Consequently, this resulted in a controlled decompression of the cabin in descent mode, which was identical to the system behavior for a high airfield landing operation. In this case, the cabin altitude would have been controlled to the maximum value of 14,000 feet.

The landing field elevation value that was transmitted to the ECAM was the uncorrupted value of 96 feet, while the excessive cabin altitude warning was suppressed.

Referring to the analysis shown (sub-section 1.16.4), the Investigation believes that the corrupted memory effects were, most probably, caused either by a single event upset (SEU) in one memory cell of CPC1, or by erroneous data caused by fatigued soldered joints of the integrated circuits (IC702 and 703) on the main board of CPC1.

The maintenance actions, which were implemented to rectify the pressurization system problems that continued for a period of six weeks before the Incident flight, were in accordance with the *AMM* and *TSM*. However, they did not resolve the pressurization system malfunctions.

The Aircraft manufacturer has taken safety action by developing a CPC that will avoid the memory corruption issue or erroneous data on the CPC. In order to avoid reoccurrence, while awaiting for the upcoming modified CPC, the Investigation recommends that the Operator consider including CPC issues in its reliability system during the Investigation. The Operator took safety action by issuing an alert notification for further detailed monitoring of its CPC units (see further sub-section 4.2.2).

The Investigation recommends that the Aircraft manufacturer issue a technical publication to be shared with all A320 operators explaining the current CPC issue as experienced in this Incident flight, in order to avoid a similar future problem.

2.3.1 Cabin pressure – low differential pressure caution

As designed, a low differential pressure CAB PR LO DIFF PR caution on the ECAM was triggered when the aircraft pressure altitude was about to overrun the cabin altitude due to a rapid descent. Hence, the low differential pressure warning could only be triggered in descent mode.

The flight crew noticed that the cabin altitude was increasing during descent, and therefore they performed an emergency descent. Consequently, the Aircraft pressure altitude would overrun the cabin altitude, and trigger the low differential pressure message that appeared at 1338.

The cabin differential pressure (Δp) became zero at about 1339:07 as the Aircraft was descending through 10,380 feet pressure altitude and the cabin pressure was at the same altitude.

The design logic of the low differential pressure caution is such that the alert will trigger when the following conditions occur: The time to reach $\Delta p = 0$ is less than 1.5 minutes; the time to reach $\Delta p = 0$ is less than the time for CAB ALT to reach landing field elevation +30 seconds; and the aircraft is at least 3,000 feet above the landing field elevation.

Using this logic, the Investigation believes that the low differential pressure caution alert was, most probably, triggered at about 1338:16, as the Aircraft was descending through 13,576 feet pressure altitude (the same value as the maximum cabin altitude that occurred in this event (10,576 feet) + 3,000 feet). The corrupt landing field elevation was about 10,576 feet, which had been used by CPC1.

2.3.2 Warning of cabin pressure safety valve opening

The safety valve limits the differential pressure between the cabin pressure and the ambient pressure in order to protect the fuselage. As designed, the valve operates in both



directions, overpressure from the cabin to ambient that is a positive differential pressure, and vice versa overpressure from ambient to cabin that is a negative differential pressure.

If a specified differential cabin pressure and ambient pressure is reached, the safety valve will release any overpressure. Only after the safety valve has remained open for at least 60 seconds will a display in the cockpit (ECAM) indicate that the safety valve has opened.

In this flight, at 1340, a 'CAB PR SAFETY VALVE OPEN' message appeared on the ECAM. This means that the Aircraft pressure altitude overran the cabin altitude (the Aircraft pressure altitude was less than the cabin altitude) with a negative differential pressure of more than one psi ($\Delta p < -1$ psi), and this had occurred at 1339. This condition remained for about one minute, and then the ECAM warning message was triggered at 1340. However, the minimum differential pressure was -0.59 psi, which means that it had never reached less than -1 psi.

Based on the maintenance PFR, the cabin pressure safety valve (2) opened at 1340. The number two between brackets (2) indicates that the safety valve reacted to the overpressure condition twice. Only the first occasion on which the safety valve opened was recorded in the PFR, while the subsequent safety valve openings could be derived from the number in brackets but the occasions on which the safety valve opened could not be attributed to precise times.

Most probably, the first safety valve opening occurred as the Aircraft was descending between 10,000 and 8,900 feet pressure altitude.



3. Conclusions

3.1 General

From the evidence available, the following findings, causes, and contributing factors were made with respect to this Incident. These shall not be read as apportioning blame or liability to any particular organization or individual.

To serve the objective of this Investigation, the following sections are included in the Conclusions heading:

- **Findings.** Are statements of all significant conditions, events or circumstances in this Incident. The findings are significant steps in this Incident sequence but they are not always causal or indicate deficiencies.
- **Causes.** Are actions, omissions, events, conditions, or a combination thereof, which led to this Incident.
- **Contributing factors.** Are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the Incident occurring, or mitigated the severity of the consequences of the Incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

3.2.1 Findings relevant to the Aircraft

- (a) The Aircraft was certificated, equipped, and maintained in accordance with the requirements of the *Civil Aviation Regulations* of the United Arab Emirates.
- (b) The Aircraft was airworthy when dispatched for the flight based on the performed troubleshooting and tests of the pressurization system in accordance with the *troubleshooting manual (TSM)* and *aircraft maintenance manual (AMM)*, which had been found satisfactory. However, not all the rectification actions identified the historical and real problem.
- (c) The Aircraft maintenance records revealed that cabin pressure system 1 had experienced an excessive cabin pressure during the descent until touchdown, on the previous flight. The avionic skin air outlet valve was found faulty, therefore it was replaced with a new one which passed the operational check in accordance with the *AMM*.
- (d) It was determined after the Incident that the Operator's troubleshooting actions taken during the six weeks prior to the Incident could not identify the root cause of the cabin pressurization issues.
- (e) The slow cabin depressurization started to occur as the Aircraft was descending through 34,200 feet pressure altitude from the top of descent FL370.
- (f) The cabin pressure excess warning triggered when the cabin altitude reached 9,536 feet, and the Aircraft was passing approximately 19,450 feet pressure altitude (19,200 feet pressure altitude indicated in the cockpit).
- (g) CPC1 was the system in control; however, it did not trigger the cabin pressure excess warning while controlling the cabin towards higher altitudes with a cabin vertical rate of 300 to 400 feet per minute.



- (h) CPC2 triggered the excessive cabin altitude warning when the cabin altitude reached 9,536 feet. The landing field elevation was 96 feet, which was about the same as OPKC airport elevation.
- (i) The CAB PR LO DIFF PR caution, most probably, triggered when the Aircraft was descending through 13,576 feet pressure altitude.
- (j) CPC1 used a corrupt landing field elevation of about 10,576 feet.
- (k) The cabin differential pressure (Δp) became zero as the Aircraft was descending through 10,380 feet pressure altitude.
- (l) The maximum cabin altitude reached was 10,576 feet, as the Aircraft was descending through approximately 9,500 feet pressure altitude.
- (m) The safety valve opened twice, and the first safety valve opening, most probably, occurred as the Aircraft was descending between 10,000 and 8,900 feet pressure altitude and the valve stayed open for more than one minute.
- (n) As the Aircraft reached 8,000 feet pressure altitude, and maintained at that level, the excessive cabin pressure warning disappeared with a cabin altitude of approximately 9,200 feet.
- (o) The corrupt landing field elevation value occurred due to a bit corruption in the memory cell of the digital electronic system of CPC1.
- (p) The corrupted memory effect was caused either by a single event upset (SEU) in one memory cell of CPC1, or due to erroneous data caused by fatigued soldered joints of ICs (IC702 and 703) on the main board of CPC1.

3.2.2 Findings relevant to the flight crewmembers

- (a) The flight crewmembers were licensed and qualified for the flight in accordance with the existing requirements of the *Civil Aviation Regulations* of the United Arab Emirates.
- (b) The manual deployment of the passenger oxygen masks was an early precautionary action taken by the flight crew, which is believed by the Investigation to have been unnecessary.
- (c) With the exception of the manual deployment of the passenger oxygen masks, both flight crewmembers operated the flight in accordance with the Operator's *standard operating procedures (SOP)*. They implemented all necessary checklists, including the abnormal and emergency checklist, for the cabin pressurization failure.
- (d) Both flight crewmembers maintained good situational awareness during the Incident flight.

3.2.3 Findings relevant to flight operations

- (a) During the descent, passing approximately FL280 from the top of descent, the flight crew questioned the functionality of the cabin pressurization system. They expected the cabin altitude to reduce, but instead, it increased.
- (b) The Aircraft was levelled off at FL270 in order to assess the problem and see if there was any improvement, and to make any necessary decisions, and take appropriate action(s).
- (c) As the Aircraft was maintaining level at FL270, the cabin altitude increased continuously, and the Commander decided to continue the descent.



- (d) The Commander decided to don the flight crew oxygen masks when the cabin pressure almost reached 9,000 feet and the Aircraft was descending through 25,700 feet.
- (e) An emergency descent was initiated when the Aircraft was descending through FL250.
- (f) The passenger oxygen masks were deployed manually, and the Commander advised the passengers that the Aircraft was performing an emergency descent, and instructed the passengers to use the deployed oxygen masks immediately. The instruction to use the oxygen masks was given as the Aircraft was passing about 16,400 feet pressure altitude.
- (g) Both flight crew removed their oxygen masks when the Aircraft reached 10,000 feet pressure altitude.
- (h) When the Aircraft leveled off at FL80, the Commander advised that the passenger oxygen masks could be removed since the altitude of the Aircraft was low and in safe condition, after the excessive cabin pressure warning disappeared.
- (i) The cabin pressurization system was set to 'Manual Mode' as the Aircraft was descending through 7,800 feet pressure altitude.
- (j) After the Aircraft state was in a normal and safe condition, the Commander provided a NITS briefing to the cabin manager about the cabin pressure issue and the actions taken.

3.3 Causes

The Air Accident Investigation Sector determines that the cause of the Incident was the slow depressurization of the cabin during descent due to the number one cabin pressure controller (CPC1) processing corrupt landing field elevation data.

The corrupt value for the landing field elevation was, most probably, caused by a bit corruption in the memory cell of the digital electronic system of the CPC1, which led the flight crew to carry out an emergency descent and to manually deploy the passenger oxygen masks.

3.4 Contributing Factors to the Incident

The Air Accident Investigation Sector identifies the following contributing factors to the Incident:

- CPC1 as the system that was controlling the cabin pressure control system did not trigger an excessive cabin pressure warning while controlling the cabin towards higher altitude of the landing field elevation, with a cabin altitude rate of 300 to 400 feet per minute. However, the CPC2 triggered the excessive cabin altitude warning when the cabin altitude reached the warning threshold. The landing field elevation used by CPC2 was 96 feet, which was approximately the OPKC airport elevation.
- The corrupted memory was, most probably, caused either by a single event upset (SEU) in one memory cell of CPC1, or by erroneous data caused by fatigued solder joints on the ICs of the main board of the CPC1.

4. Safety Recommendations

4.1 General

The safety recommendations listed in this Report are proposed according to paragraph 6.8 of *Annex 13 to the Convention on International Civil Aviation*, and are based on the conclusions listed in part 3 of this Report; the Air Accident Investigation sector expects that all safety issues identified by the Investigation are addressed by the concerned organizations.

4.2 Safety Actions Taken

4.2.1 Airbus

The Aircraft manufacturer, Airbus, is developing a CPC that will avoid the issue of memory corruption or submitting erroneous data to the CPC. However, no consolidated planning could be communicated so far.

4.2.2 Etihad Airways

The maintenance actions which were implemented to rectify the pressurization system problems that continued for a period of six weeks prior to the Incident flight, were in accordance with the *aircraft maintenance manual (AMM)* and *troubleshooting manual (TSM)*. However, they did not resolve the pressurization system malfunctions.

Airbus is in the process of modifying the cabin pressure controller (CPC) to prevent memory corruption or erroneous data input to the CPC, as mentioned in sub-section 4.2.1. The CPC units are already reliability monitored as per Etihad's reliability program, and after the Incident, Etihad took safety action by issuing an alert notification for further detailed monitoring of its CPC units. The alert notification was raised by the Operator since the involved CPC unit, including other CPC units, exceeded the alert level, or have high defects/delay rates. Airbus was informed of the alert notification.

4.3 Final Report Safety Recommendations

The Air Accident Investigation Sector recommends that:

4.3.1 Etihad Airways

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Although the manual deployment of the passenger oxygen masks was not a contributing factor to the Incident, the manual deployment of the passenger oxygen masks was not in line with the *FCOM SOP* for cabin pressure excess.

Therefore, the Investigation recommends that the Operator promulgate details of this Incident to all flight crewmembers and include appropriate aspects of the Incident in flight crew training. In particular, the action of the flight crew, which was not in accordance with the *SOP*, in manually deploying the oxygen masks should be referred to in the distributed information and training.

4.3.2 Airbus

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As the safety action of modifying the CPC is in progress, and while waiting for the modified CPC to become available, the Investigation recommends that Airbus issue a technical publication to be shared with all A320 operators explaining the current CPC issue as experienced in this Incident.



This Report is issued by:

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Appendix 1. Detailed Events

The detailed event descriptions based on the relevant DFDR read-out, CVR playback, and the analysis of the CPC non-volatile memory, were examined as given below. Prior to that, the time between the data was synchronized.

At 1216:05, after the Tower provided take-off clearance including the wind surface information, the Aircraft entered runway 31R and the flight crew performed rolling takeoff for the departure. After the takeoff and climb, the Aircraft cruised at FL 370.

Before the top of descent, the flight crew went through the decent preparation as per *FCOM*.

At 1321:14, the Commander made a PA and briefed the passengers that the Aircraft would descend within about five minutes.

At 1327:08, the Co-pilot contacted ATC and requested to descend. The ATC instructed to descend the Aircraft to FL150. Thereafter, the Aircraft then started to descend from FL370.

Before the descent, pack 1 and 2 flow control valves were opened, and stayed open until landing. The engine 1 and 2 pressure regulated valves (PRV) were opened, and stayed open until landing. The engine 1 and 2 HP valves (HPV) were closed. The PRV1 was 40.5 psi, while PRV2 was 38.5 psi. The ECAM system display (SD) was on cruise page (SD CRUISE).

At 1327:27, the Aircraft started to descend from the FL370 top of descent for arrival into OPKC.

Between 1327:44 and 1328:51, the engine 1 and 2 HP valves (HPV) opened.

Between 1329:05 and 1333:43, the engine 1 and 2 HP valves (HPV) opened.

At 1332:30, during descending through 28,350 feet pressure altitude, the Co-pilot questioned whether the cabin vertical speed was normal. Then, the ECAM SD CAB PRESS (cabin pressure) page was selected which provided precise information of the cabin pressurization system to the flight crew. Before the selection of ECAM SD CAB PRESS page, SD CRUISE page was set. The ECAM SD CAB PRESS page provided more information about the cabin pressurization system compared to SD CRUISE.

The cabin vertical speed was increasing; however, it supposed to be reducing as discussed and agreed by both flight crew. The Co-pilot mentioned that the cabin altitude was 7,900 feet, and therefore, the Commander mentioned to the Co-pilot that they needed to reduce the rate.

At 1332:41, the PRV1 was 25.5 psi, while PRV2 was 24.5 psi. The ECAM system display on pressurization system page (SD PRESS) was displayed.

At 1333:05, when the Aircraft was descending passing 27,350 feet pressure altitude, the Co-pilot mentioned that the cabin altitude was 8,000 feet. At this moment both flight realized that there was a problem with the cabin pressurization system.

Therefore, the Commander requested the Co-pilot to contact and request ATC to maintain the Aircraft at about FL270.

At 1333:25, SD CRUISE was displayed.

At 1333:28, the Aircraft started to level off. While the Aircraft was maintaining level at FL 270, both flight crew realized that the cabin altitude was still increasing continuously. The Commander then decided to descend the Aircraft, and 'open descent' mode was set.



At 13:33:41, the PRV1 was 35 psi, while PRV2 was 37 psi. SD PRESS was displayed.

Between 1333:52 and 1340:48, the engine 1 and 2 HP valves (HPV) opened.

At 1334:18, the cabin altitude was 8,464 feet.

The Aircraft maintained level at FL 270 for about one minute.

At 1334:38, the Aircraft started to descend, and The ATC then instructed to contact Karachi Approach on frequency 125.5 MHz.

The flight crew discussed that they would need to put the oxygen masks since there was no improvement of the cabin altitude, instead of decreasing the cabin altitude continued to increase. However, the Commander mentioned to wait for a while to see further progress of the issue.

At 1334:48, the cabin altitude was 8,656 feet.

At 1334:59, the Co-pilot then informed Approach controller that the Aircraft would continue to descend to FL150.

At 1335:11, the Commander decided to use the oxygen masks since the cabin pressure almost reached 9,000 feet, which agreed by the Co-pilot. At this moment, the Aircraft was descending passing 25,700 feet.

At 1335:14, the oxygen masks were used when the Aircraft was descending through 25,550 feet pressure altitude. The flight crew then checked the readability of their internal communication with masks, which had no any issues.

At 1335:18, the cabin altitude was 8,848 feet.

The Commander then performed a rapid descent by increasing the descent vertical speed approximately from -2,400 down to -5,870 feet per minute gradually.

While performing the rapid descent, the Co-pilot called out 'ECAM advisory', which then responded by mentioning 'checked' by the Commander. Hence, ECAM advisory was set in order to advice the flight crew with abnormal and emergency procedure of cabin pressurization system, which was displayed on the ECAM SD pages.

At 1335:48, the cabin altitude was 9,040 feet.

At 1336:03, when the Aircraft was passing approximately 23,000 feet pressure altitude, the Commander informed the passengers that they were performing emergency descent. The Cabin altitude was 9,152 feet.

At 1336:14, when the Aircraft was passing approximately 22,200 feet pressure altitude, the Co-pilot then informed ATC Approach that they were performing emergency descent due to cabin pressure failure, and declared PAN PAN.

At 1336:33, the cabin altitude was 9,344 feet.

At 1336:35, the Aircraft was passing through 20,900 feet pressure altitude and the ATC instructed the flight crew to descend the Aircraft to FL110, which then read back correctly by the Co-pilot. Hence, the selected altitude was set to 11,000 feet when the Aircraft was passing 20,500 feet pressure altitude.

At 1337:03, according to the ECS maintenance report, the Aircraft was passing approximately 19,450 feet pressure altitude, and the cabin pressure excess warning triggered. The cabin altitude was 9,536 feet. The warning triggered in the cockpit approximately two seconds later, at 1337:05, and the PRV1 was 24 psi, while PRV2 was 23.5 psi.

The Commander then mentioned to perform the related *FCOM* procedure.



At 1337:14, when the Aircraft was passing approximately 18,750 feet pressure altitude, the flight crew started going through the *FCOM* procedure for the triggered cabin pressure excess warning. They went through the procedure properly.

At 1337:40, at the end of the procedure, the passengers' oxygen masks were deployed manually, when the Aircraft was passing about 16,400 feet pressure altitude. The Commander then mentioned to the passengers through PA, that the Aircraft was performing emergency descent, and instructed the passengers to use the deployed oxygen masks immediately. The cabin crews also ensured that all passengers used the masks.

At 1338:15, when the Aircraft was passing 13,600 feet pressure altitude, the ATC Approach provided clearance to the Aircraft to descend to FL80. The selected altitude was then set to 8,000 feet.

During emergency descent, autopilot (AP1) and autothrust were engaged.

At 1339:01, the ECAM status page (STATUS) was displayed, as the STS pushbutton was pressed on the ECAM control panel (ECP).

At 1339:24, both flight crew removed their oxygen masks when the Aircraft reached 9,900 feet pressure altitude.

When the Aircraft was passing 9,700 feet pressure altitude, the Commander asked the Co-pilot to inform ATC that they completed the emergency descent, which then performed by the Co-pilot.

At 1339:38, the Aircraft was passing 9,580 feet pressure altitude, and the Co-pilot informed ATC that EY200 completed the emergency descent, and cancelled PAN-PAN.

At 1339:55, the ATC Approach instructed the flight crew to turn left onto heading 075 degrees for approaching ILS runway 25L when the Aircraft was descending passing 9,100 feet pressure altitude, on a heading of 085 degrees.

At 1340:09, ECAM SD CRUISE page was displayed.

At 1340:16, the Commander mentioned to the Co-pilot that the cabin pressure was going down through 9,800 feet, when the Aircraft was descending through 8,300 feet pressure altitude.

At 1340:25, ECAM SD CAB PRESS page was displayed.

At 1340:37, the excessive cabin pressure warning disappeared. At this time, the Aircraft reached 8,000 feet pressure altitude and maintained at that level, and the Commander asked the cabin manager whether everything was all right which then answered that there was no issue with all passengers. The Commander then briefed the cabin manager that the passenger oxygen masks could be relieved since the altitude of the Aircraft was low and safe. In addition, he explained that the Aircraft condition was normal again and would have a normal landing.

At 1341:15, the ATC instructed the flight crew to descend and maintain FL70, which then replied correctly by the Co-pilot. The selected altitude was selected to 7,000 feet at 1341:22, consequently, the Aircraft started to descend with an average vertical speed of 400 feet per minute.

At 1342:01, the flight crew set the cabin pressure to 'Manual Mode' when the Aircraft was descending passing 7,800 feet pressure altitude. The Commander then provided NITS briefing to the cabin manager.

During the descent to FL70, the flight crew observed that the cabin altitude was descending slowly.



When the Aircraft was passing 7,430 feet pressure altitude, the Commander asked for the 'Aircraft status', which then they reviewed the setting of the manual cabin pressure mode, such as the minimum target cabin pressure, and the descent rate of the cabin altitude. They also briefed the approach procedures, and put the required setting for ILS runway 25L approach navigation (flight management position approaches, radio position, etc.).

At 1342:57, ECAM SD CRUISE page was displayed.

At 1343:54, when the Aircraft was descending through 7,100 feet pressure altitude, ATC instructed the flight crew to descend and maintain to FL50, which then correctly read back by the Co-pilot. The selected altitude was then set to FL50.

The Co-pilot mentioned 'remove status', which acknowledged by the Commander, when the Aircraft was passing 6,430 feet pressure altitude.

At 1344:53, the Aircraft was passing 6,270 feet pressure altitude. The Commander mentioned that the cabin altitude was decreasing, and the Co-pilot mentioned that the cabin vertical speed should be 300 feet per minute as the target. The Commander then mentioned that the cabin altitude needed to be lowered as much as possible.

When the Aircraft was descending through 6,000 feet pressure altitude, at 1345:08, the Commander requested the Co-pilot to brief the approach checklist, which then performed correctly as per *FCOM*.

At 1345:23, the ATC instructed the flight crew to descend the Aircraft to 3,000 feet, and provided the QNH of 1012 mbar when the Aircraft was passing 5,750 feet pressure altitude. Hence, the selected altitude was set to 3,000 feet. Thereafter, the flight crew continued with the approach briefing since the briefing was yet finished, when ATC instruction came. The minimum height was set to 318 feet as the decision height.

Both barometric setting were then set to 1012 mbar when the Aircraft reached approximately 4,900 feet pressure altitude, which was below the transition level FL50.

At 1346:34, the Commander mentioned that the cabin altitude was decreasing through 5,000 feet, when the Aircraft was descending passing 4,440 feet pressure altitude.

When the Aircraft was descending passing 3,340 feet, the Co-pilot mentioned that the cabin pressure altitude was more than the Aircraft pressure altitude.

At 1348:09, when the Aircraft just reached 3,000 feet pressure altitude and maintained that level, the Commander requested ATC Approach whether the Aircraft could stay a bit longer on downwind in order to reduce the cabin pressure manually, which was then approved by the Controller. The Commander replied the ATC, and informed that the Aircraft would maintain 3,000 feet pressure altitude on heading 075 degrees.

At 1349:00, the Commander asked the Co-pilot about the cabin altitude, and replied that it was descending through 3,000 feet.

At 1349:28, the cabin altitude was descending through 2,600 feet, while the Aircraft was still maintaining level at 3,000 feet pressure altitude.

The flight crew was trying to put back the cabin pressurization system to automatic mode, and it resulted into an increased cabin altitude, which was still abnormal. Hence, it was set back to manual mode to lower the cabin altitude. The Co-pilot mentioned that he would keep lowering the cabin altitude until it would reach zero feet.

The Commander mentioned to the Co-pilot that the Aircraft could descend and turn in order to comply the Jeppesen standard arrival (STAR) for runway 25L/R.

At 1351:01, the ATC Approach instructed the flight crew to turn left when ready onto heading 340 degrees (base leg). The Commander then replied that the Aircraft started turning.



At 1352:23, the ATC Approach instructed the flight crew to turn left when ready onto heading 280 degrees for ILS approach runway 25L, and to report when establishing the ILS.

At 1352:41, the cabin altitude was descending through 900 feet as mentioned by the Commander, while the Aircraft was maintaining 3,000 feet pressure altitude.

At 1353:11, the Co-pilot informed ATC Approach that the Aircraft established on the localizer, when it was turning left through 270 degrees. The Controller instructed to continue the ILS approach runway 25L.

The flight crew then discussed about the cabin pressure issue, which was strange for them.

At 1355:20, the glideslope was alive when the Aircraft was at 11 nautical miles DME, while maintaining level at 3,000 feet pressure altitude on 253 degrees heading.

At 1355:51, the Aircraft was at nine nautical miles DME, the glideslope was captured, and the Aircraft started to descend. The glideslope became on track mode when the Aircraft was at eight nautical miles DME at 1356:06.

At 1356:23, ATC Approach instructed the flight crew to contact ATC Tower on 118.3 MHz. The Co-pilot read back correctly.

At 1356:36, the Co-pilot contacted ATC Tower informing that the Aircraft was established on the ILS runway 25L, and requested wind surface information. ATC Tower provided wind surface information of 250 degrees direction with a speed of 10 knots. ATC Tower also provided clearance to land, which then read back correctly by the Co-pilot.

At 1356:58, the Commander requested the Co-pilot to have the landing checklist, which then performed by the flight crew when the Aircraft was at six DME.

The Aircraft landed uneventful at 1359:46.

The engines were shut down at 1405:53.



Appendix 2. Post Flight Report

The post flight report of the flight is shown in figure A2.1.

A/C ID	DATE	GMT	FLTN	CITY PAIR
.A6-EIF	05MAR	1514	ETD200	OMAA OPKC

MAINTENANCE		DB/N
POST FLIGHT REPORT		EY32091602BDR

A/C ID	DATE	GMT	FLTN	CITY PAIR
.A6-EIF	05MAR	1207/1402	ETD200	OMAA OPKC

WARNING/MAINT.STATUS MESSAGES

GMT	PH	ATA	MESSAGE
1207	02	21-26	VENT AVNCS SYS FAULT
1216	02	31-00	DAR
1216	04	21-26	VENT BLOWER FAULT
1232	06	31-00	DAR (5)
1337	06	21-31	CAB PR EXCESS CAB ALT
1340	06	21-31	CAB PR SAFETY VALVE OPEN (2)
1351	06	31-00	DAR
1400	09	21-26	VENT AVNCS SYS FAULT
1400	09	21-26	VENT BLOWER FAULT

FAILURE MESSAGES

GMT	PH	ATA	MESSAGE	SOURCE	IDENT.
1207	02	73-21-60	AFS:FADEC2	AFS	
1216	02	31-36-52	DAR(2TV)	DMU	
1217	06	21-26-34	AEVC	AEVC	
1217	06	21-26-51	BLOWER FAN 20HQ	AEVC	
1359	08	22-83-34	AFS:FNGC1	AFS	

Figure A2.1. Post flight report of the flight