Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accident Investigation

Investigation Report

Identification

Type of Occurrence:	Serious incident
Date:	4 April 2012
Location:	Near Lugano, Switzerland
Aircraft:	Airplane
Manufacturer / Model:	Boeing / 737-800
Injuries to Persons:	13 persons suffered minor injuries
Damage:	None
Other Damage:	None
Information Source:	Investigation by BFU
State File Number:	BFU FX003-12

Factual Information

On a passenger flight from Bergamo, Italy, to East Midlands, Great Britain, depressurisation occurred in Swiss airspace during the climb to cruise level. The crew performed an emergency descent and landed the airplane at Frankfurt-Hahn Airport.

Thirteen passengers suffered minor injuries.

The Swiss Accident Investigation Board (SAIB) delegated the investigation into the occurrence to the German Federal Bureau of Aircraft Accident Investigation (BFU).

History of the Flight

At 1056[1] hrs the airplane had taken off from Bergamo Airport (LIME) to a scheduled service to East Midlands (EGNX). Six crew members and 134 passengers were aboard the airplane.

About 13 minutes after take-off, the airplane was in climb above the Swiss Alps approximately 30 NM north of Lugano in Swiss airspace when the crew noticed a sudden change in cabin pressure. They reported it had manifested through a draft, a decrease in temperature and pressure in the ears. The indication for the cabin rate change had been at the maximum climb indication of 4,000 ft/min and the cabin altitude had exceeded 10,000 ft. The crew donned their oxygen masks and the Pilot in Command (PIC) requested completion of the Cabin Altitude Warning/Rapid Depressurization checklist.

The data of the Flight Data Recorder (FDR) showed that at 1108:40 hrs the Master Caution and about 20 seconds later the cabin altitude warning (cabin altitude > 10,000 ft) was triggered. The warning ceased about two minutes later.

The recordings of the Cockpit Voice Recorder (CVR) showed that the co-pilot said: "So, master caution, air-conditioning […] climb." The PIC answered: "I think this is air-conditioning, four thousand feet a minute […] I think I call rapid [...] cabin altitude pressurization check list." Subsequently the two pilots donned their oxygen masks, checked the communications and started completion of the checklist.

At 1109:47 hrs the co-pilot said: "… set manual […] close." Seventeen seconds later the PIC said: "Okay and oxygen masks […] passenger oxygen system on, please." At 1110:14 hrs he said: "Okay it's not controlling, it's not controlling, right to emergency desc… do you agree? It's not controlling, it's above ten thousand feet, right to emergency descent checklist."

The crew initiated an emergency descent. At 1111:19 hrs the co-pilot reported via radio: "Mayday, mayday, mayday […], we have a rapid depressurization. Emergency descent. Descending to […] next would be flight level one hundred, turning left on heading two eight five." The controller answered: "[…] roger, mayday is observed." Immediately afterwards the airplane began to descent and turned north-west. Initially the rate of descent reached more than 6,000 ft/min and after about 20 seconds decreased to about 4,000 ft/min. The altitude was decreased to Flight Level (FL) 130 and then to FL100.

1 All times local, unless otherwise stated.

According to the radar data the aircraft had been in FL308 when the descent was initiated. At the beginning of the emergency descent of the B737-800 a brief airprox (4.5 NM horizontally and about 325 ft vertically) with an Airbus A319 flying in FL300 also north occurred.

At 1116 hrs the airplane stopped the descent in FL100. The crew decided to fly to Frankfurt-Hahn Airport. The airplane landed there without further problems.

The purser stated she had noticed a sudden change in pressure and reduction of temperature in the cabin. Ten to twenty seconds later the oxygen masks in the cabin had deployed. A few passengers had had brief problems putting their masks on.

According to police information one passenger had suffered a ruptured ear drum; twelve other passengers were treated for earaches.

Personnel Information

Pilot in Command (PIC)

The 31-year-old PIC was a citizen of Great Britain and held an Air Transport Pilot's License (ATPL(A)) issued by the Irish civil aviation authority in accordance with ICAO and JAR-FCL on 29 August 2009 valid to 28 August 2014. The type rating for the B737-300-900 was valid to 31 December 2012.

His class 1 medical certificate was valid to 8 May 2013.

He had a total flying experience of about 6,000 hours; 5,800 of which on the type in question.

Co-pilot

The 30-year-old co-pilot was a citizen of Great Britain and held a Commercial Pilot's License (CPL) issued by the Irish civil aviation authority on 9 January 2012 valid to 8 January 2017.

Since 6 December 2011 he held the type rating for the B737-800 valid to 31 December 2012.

His medical class 1 certificate was valid until 30 May 2012.

His total flying experience was about 820 hours; 120 hours of which on the type in question.

Purser

In May 2007, the flight attendant had completed the Initial Safety Training for the B737-800.

Her total flying experience was about 4,500 hours.

Aircraft Information

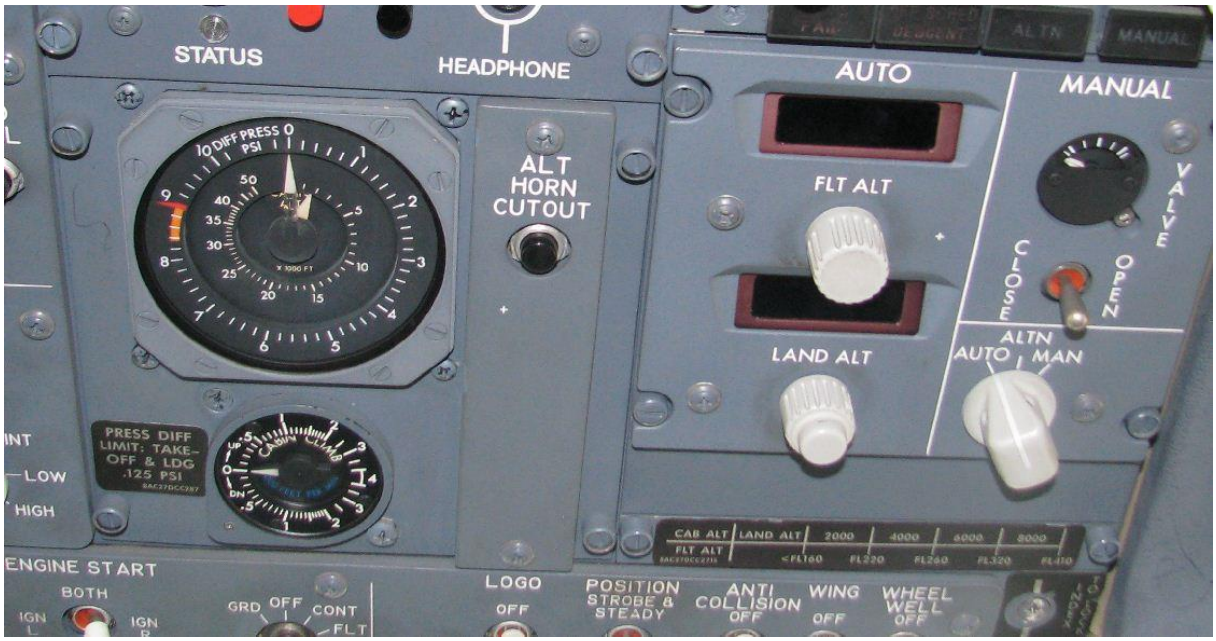
Manufacturer:	Boeing
Type:	B737-8AS
Manufacturer's Serial Number (MSN):	33546
Year of manufacture:	2003
MTOM:	66,900 kg
Engines:	CFM International, CFM56-7B

The aircraft had a valid Irish certificate of registration and was operated by an Irish operator.

At the time of the occurrence the airplane had a total of 31,180 operating hours and 20,400 flight cycles.

The pressurized cabin consisted of the main assemblies: airframe, air-conditioning packs, an outflow valve, an overpressure relief valve and a negative pressure relief valve. Two Cabin Pressure Controllers (CPC) controlled the cabin rate of which one at a time actively controlled the outflow valve. The second CPC served as the redundant system.

The operating and indication panel of the digital cabin pressure control system was part of the overhead panel in the cockpit. Indications for the cabin altitude and the differential pressure, the cabin rate of climb indicator (maximum 4,000 ft/min) and the outflow lave position indicator were installed.



Digital Cabin Pressure Control System Photo: BFU

The Quick Reference Handbook (QRH) included the checklist Cabin Altitude Warning/ Rapid Depressurization with the following instructions:

1 Don oxygen masks and set regulators to 100%.

2 Establish crew communications.

3 Pressurization mode selector . . . . . MAN

4 Outflow VALVE switch . . . . . Hold in CLOSE until the outflow VALVE indication shows fully closed

5 If cabin altitude is not controllable:

Passenger signs . . . .ON

If the cabin altitude exceeds or is expected to exceed 14,000 feet:

PASS OXYGEN switch . . . . . ON

►►Go to the Emergency Descent checklist on page 0.1

6 If cabin altitude is controllable: Continue manual operation to maintain correct cabin altitude.

When the cabin altitude is at or below 10,000 feet: Oxygen masks may be removed.

The Emergency Checklist Descent instructed the following:

> *1 Announce the emergency descent. The pilot flying will advise the cabin crew, on the PA system, of impending rapid descent. The pilot monitoring will advise ATC and obtain the area altimeter setting.*
>
> *2 Passenger signs . . . . . ON*
>
> *3 Without delay, descend to the lowest safe altitude or 10,000 feet, whichever is higher.*
>
> *4 ENGINE START switches (both) . . . . . CONT*
>
> *5 Thrust levers (both) . . . . Reduce thrust to minimum or as needed for anti-ice*
>
> *6 Speedbrake . . . . FLIGHT DETENT*
>
> *7 Set target speed to Mmo/Vmo.*
>
> *8 When approaching the level off altitude: Smoothly lower the SPEED BRAKE lever to the DOWN detent and level off. Add thrust and stabilize on altitude and airspeed.*

Meteorological Information

At the time of the occurrence, daylight prevailed as well as Visual Meteorological Conditions (VMC) in the altitude of the B737-800.

Communication

The radio communications recordings of the various air traffic service providers were made available for the investigation.

Flight Recorder

The aircraft was equipped with a Honeywell Solid State Flight Data Recorder (SSFDR) and a Honeywell Solid State Cockpit Voice Recorder (SSVCR). The data recorders were read out at the BFU.

The radar data were recorded by the respective air traffic service providers and made available to the BFU.

Wreckage and Impact Information

It was determined that the oxygen masks stowed next to the two pilot seats in the cockpit were pulled out.

In the cabin all the oxygen masks had deployed. At the following positions the oxygen masks had not been pulled out and the generators were not activated: seat rows 2, 3, and 4 on the left side of the cabin and seat rows 2 and 3 on the right side; at the right overwing emergency exit and in the front lavatory.

The two CPCs were located in the electronic equipment compartment behind the nose landing gear. The static port sensor on the CPC#1 was covered with a black shipping plug.

Cabin Pressure Controller #1 Static Port Photo: BFU

Read-out of the Cabin Pressure Controllers

The recorded data of the non-volatile memory of the two CPCs was downloaded. The analysis of the data showed that during climb the CPC#2 was in control.

During the climb phase transmission errors occurred (Fault Code 39 RS422_XMIT_FAIL and Fault Code 40 RS422_WA_FAIL). Subsequently CPC#2 changed to standby and CPC#1 took over. At that time CPC#2 had measured an ambient pressure of 4.28 PSI and 4.27 PSI (about 295 hPa), respectively. This corresponds with approximately FL305. The cabin pressure was measured with 12.10 PSI and 12.09 PSI (about 833 hPa), respectively. Twelve seconds later CPC#2 recorded Fault Code 17 (CABIN_10000FT_MESSAGE). The measured ambient pressure was 4.22 PSI and the cabin pressure 10.10 PSI. The cabin rate of climb was measured with 6776.25 ft/min at that time. Six seconds later Fault Code 18 (CABIN_13500FT_MESSAGE) was recorded. The measured ambient pressure was 4.20 PSI (289 hPa) and the cabin pressure 8.80 PSI (607 hPa). At that time, the cabin rate of climb was at 7656.5 ft/min.

CPC#1 recorded a cabin pressure of 15.16 PSI (1,045 hPa) and an ambient pressure of 4.20 PSI. According to the CPC recording the outflow valve was open by 76.83°. At that time, Fault Code 90 (OFV_CAB_PRESS_SWITCH_Active) was recorded. About 36 seconds later CPC#1 recorded Fault Code 58 (MANUAL_MODE_SWITCH_Active). At that time the cabin pressure measured by CPC#1 was 15.16 PSI and the ambient pressure 4.21 PSI. In regard to the Fault Code 58 the Intermittent Count entry was 2.

Fire

There was no fire.

Additional Information

On the day prior to the occurrence problems with the cabin pressure control system had occurred during a flight. The crew had reported these problems by entering them into the technical logbook.

As a result of the technical log entries maintenance work was carried out during the night and the data of the two cabin pressure controllers downloaded to analyse the recorded current and former fault codes from the Non-Volatile Memory (NVM). No

fault codes were found. The subsequently conducted ground tests of the two CPCs did not produce any fault codes either. The CPC#1 was changed due to the problems which had occurred during the previous flight.

The BFU is in the possession of a written statement of one of the maintenance employees which describes the content and process of the maintenance work carried out the night before the serious incident. The operator stated the employee held the license for certified category B2 personnel (Avionic). He stated that during the night he had downloaded the CPC data from the non-volatile memory. Afterwards he had assisted in finding out which of the two CPCs had been "in control" during the previous flights. The NVM had not recorded any fault codes. Subsequently carried out pressurization system ground tests on both CPCs did not reveal any faults. Since they had to wait for a spare part to arrive the work on the airplane had been interrupted and continued early the next morning after the spares arrived. Among the maintenance actions taken, the CPC#1 was changed as precautionary action. During installation of the CPC he had forgotten to remove the shipping plug. The employee of the maintenance organisation attributed this to being "over-familiar with the procedure" because he had conducted the procedures and tests several times during the night but on the CPC installed in the airplane.

After the maintenance work the aircraft had flown from East Midlands to Bergamo in a cruising altitude of FL370. During the flight CPC#2 had been "in control". No problems had occurred.

During the BFU investigation of the serious incident the maintenance organisation at Frankfurt Hahn Airport changed the two CPCs after the data had been downloaded. The replaced CPCs were equipped with shipping plugs which were yellow and larger than the ones found on the removed CPCs. They also carried a yellow tag with the sign: IMPORTANT – Remove these CAPS after installation.

Different shipping plugs of the component manufacturer Photo: BFU

Analysis

The injuries the passengers sustained during the occurrence are to be viewed as minor. The BFU classified the occurrence as serious incident and conducted an investigation due to the rapid decompression in conjunction with the necessity to use oxygen masks

According to the radar data the aircraft had been in FL308 when the descent was initiated. At 1116 hrs the airplane stopped the descent in FL100. The crew decided to fly to Frankfurt-Hahn Airport. The airplane landed there without further problems.

Technical Aspects

The active CPC#2 realised during the climb in FL305 a transmission error and therefore went changed to stand-by; CPC#1 took over. The cabin pressure measured by CPC#2 at that time was about 12.10 PSI (about 833 hPa). At the same time the cabin pressure CPC#1 measured was 15.16 PSI (1,045 hPa). This corresponds with

an altitude of -500 ft. The system logic demanded immediate opening of the Out-Flow Valve (OFV). This in turn resulted in the excessive increase of the cabin climb rate to more than 7,600 ft/min. In Automatic Mode the OFV Cabin Pressure Switch is activated at a cabin altitude of 14,500 ft. The recording OFV_CAB_PRESS_SWITCH_ACTIVE indicates that the switch closed the OFV. This is stopped, however, if on the control panel of the digital cabin pressure control system the switch is selected to Manual Mode. Thirty-six seconds after the cabin pressure switch was activated the OFV control was put into manual mode and then the opening angle of the OFV can only be controlled by the pilots. The entry Intermittent Count 2 with the Fault Code 58 MANUAL_MODE_SWITCH_ACTIVE means that the selection must have occurred three times. This means the pilots switched to manual mode, back, and once again to manual mode.

Due to the fact that the OFV_CAB_PRESS_SWITCH was activated and the high rate of climb, it must be assumed that the passenger oxygen masks were triggered automatically.

In case a CPC with a covered static port is in control from the beginning of a flight, depressurisation in the cabin occurs early and gradually. If the control change from one CPC to the next occurs in high altitudes depressurisation is immediate and more intense. It is then highly likely that an emergency descent is the result. Due to the extension of air and gases in body cavities of occupants the development of Barotrauma is possible which may result in serious injuries.

Flight Operations Aspects

The data of the flight data recorder showed that at 1108:40 hrs the master caution and about 20 seconds later the cabin altitude warning (cabin altitude > 10,000 ft) was triggered. Further six seconds later the CPC recorded a cabin altitude of 13,500 ft at a rate of climb of 7,656.5 ft/min.

The CVR recordings showed that the pilots assigned the master caution signal to the air condition and the increase in cabin altitude. The PIC noted that the cabin rate of climb had reached the maximum of 4,000 ft/min and requested the completion of the cabin altitude pressurisation checklist. In accordance with the checklist the pilots donned their oxygen masks, checked communications, and completed other items on the checklist.

One and a half minutes after the master caution had sounded the PIC estimated the cabin pressure could not be stabilised by manual control of the outflow valve and

asked the co-pilot for completion of the emergency descent checklist by saying: "Okay it is not controlling, it is not controlling, right to emergency desc… do you agree? It's not controlling, it's above ten thousand feet right to emergency descent checklist." The crew initiated an emergency descent.

At 1111:19 hrs, about one minute after this decision, the co-pilot declared emergency, informed about the rapid decompression, and the initiation of the emergency descent to FL100. Due to the fact that the airplane was above the Alps during the occurrence the emergency descent had to be conducted in phases. Nevertheless, the airplane was at FL100 within seven minutes after the beginning of the decompression.

The recordings of the CPC showed that the pilots switched the switch on the overhead panel to manual mode after the completion of the checklist to close the OFV manually. The switching was reversed and then switched back to manual mode.

Maintenance Aspects

The BFU is of the opinion that the statement of the maintenance engineer is credible. The content corresponds with the usual processes. The NVM data was downloaded and analysed in regard to fault codes. Then both CPCs were subject to multiple pressurisation system ground tests. Even though no faults or irregularities occurred, CPC#1 was replaced as precautionary action, among other things. The maintenance work was interrupted and continued early the next morning.

The maintenance engineer had stated that he had performed the procedures and tests several times during the night and that he therefore had been "over-familiar with the procedure". This means that the installation was not completely carried out in accordance with the written procedure but instead some working steps were done from memory. In doing so, he forgot to remove the shipping plug. This is called a memory lapse and is one of the most frequently described errors during maintenance work.

Defences

In the scope of this investigation, the term "Defences" means technical systems, actions, procedures and institutions which shall minimise the effects of technical and human errors to protect flight safety.

The black shipping plug did not stand out from the black surface of the CPC housing. Colour and shape of the shipping plug were very similar to the thumbscrew holddown

used to hold the avionic equipment in place. Nord Micro stated the drill hole in the shipping plug's side was meant to hold a tag. It is likely that the tag had fallen off. It could not be determined as to when the tag had fallen off. Such a tag can be viewed as a defence much as a shipping plug which is easily recognisable. In the case at hand it was not present and was insufficient, respectively.

The BFU is of the opinion that the Boeing Aircraft Maintenance Manual (AMM) clearly stipulates in the corresponding work instruction that the shipping plug has to be removed prior to installation of the CPC. The note in the Component Maintenance Manual (CMM) is also distinct. Nevertheless, the case at hand shows that at an MRO the potential for errors is given due to interruptions in the process of maintenance work or repeated tests.

The BFU is of the opinion that the shipping plug should be designed in a way that it stands out from its surroundings. This could be ensured by shape and colour. However, the BFU is of the opinion that it would be best if the shipping plug had a tag which is noticeable and long enough to cover the keys of the CPC which the maintenance personnel needs to use for the pressurisation system ground test. Mistakes would be easier recognised and eliminated and resulting consequences could be avoided.

The pressurisation system ground test conducted after the installation of the CPC was not suited to detect the error.

Conclusions

The Serious Incident was caused by the following:

Immediate Causes:

- Due to an omission during the installation of the cabin pressure controller the shipping plug was not removed from the static port as required by written procedure.
- During the flight a pressure difference was measured and the OFV opened which resulted in rapid decompression.

Systemic Causes

- The shipping plug was not clearly noticeable and did not carry a tag.
- The pressurisation system ground test after installation was not suitable to detect the error.

Safety Recommendation

On 18 June 2012 the BFU issued the following Safety Recommendations:

Recommendation No 24/2012

The Federal Aviation Administration (FAA) should require Boeing to re-design the shipping plugs in a way which makes them more recognisable. The shipping plugs should also be coupled with an eye-catching tag.

Maintenance and Repair Organisations should only cover the static ports of a cabin pressure controller with a shipping plug which is clearly visible coupled with a tag.

The FAA has sent a letter, dated 7 March 2013, to the BFU with the following statement:

> FAA Response. We conducted risk assessments using likelihood and severity and determined that the failure to remove the shipping plugs in the static pressure port does not constitute an unsafe condition. Therefore it does not meet the criteria for issuance of an Airworthiness Directive. There were reports of two 737 model aircraft dispatched with shipping plugs installed in more than 1.5 billion flights. In addition, the aircraft are designed to accommodate the failure with flight crew indications and procedures to minimize the hazard. However, we are addressing this issue with the aircraft manufacturer.
>
> Shortly after the event on July 2, 2012, Boeing began working with the supplier (Nord-Micro) to evaluate and address the cap color issue. As a result of these discussions, Nord-Micro implemented a process change to exclusively use yellow shipping plugs and orange shipping tags on cabin pressure controllers. The Boeing Certificate Management Office is ensuring the process change remains in place.

The BFU received a letter from the aircraft manufacturer dated 21 February 2014:

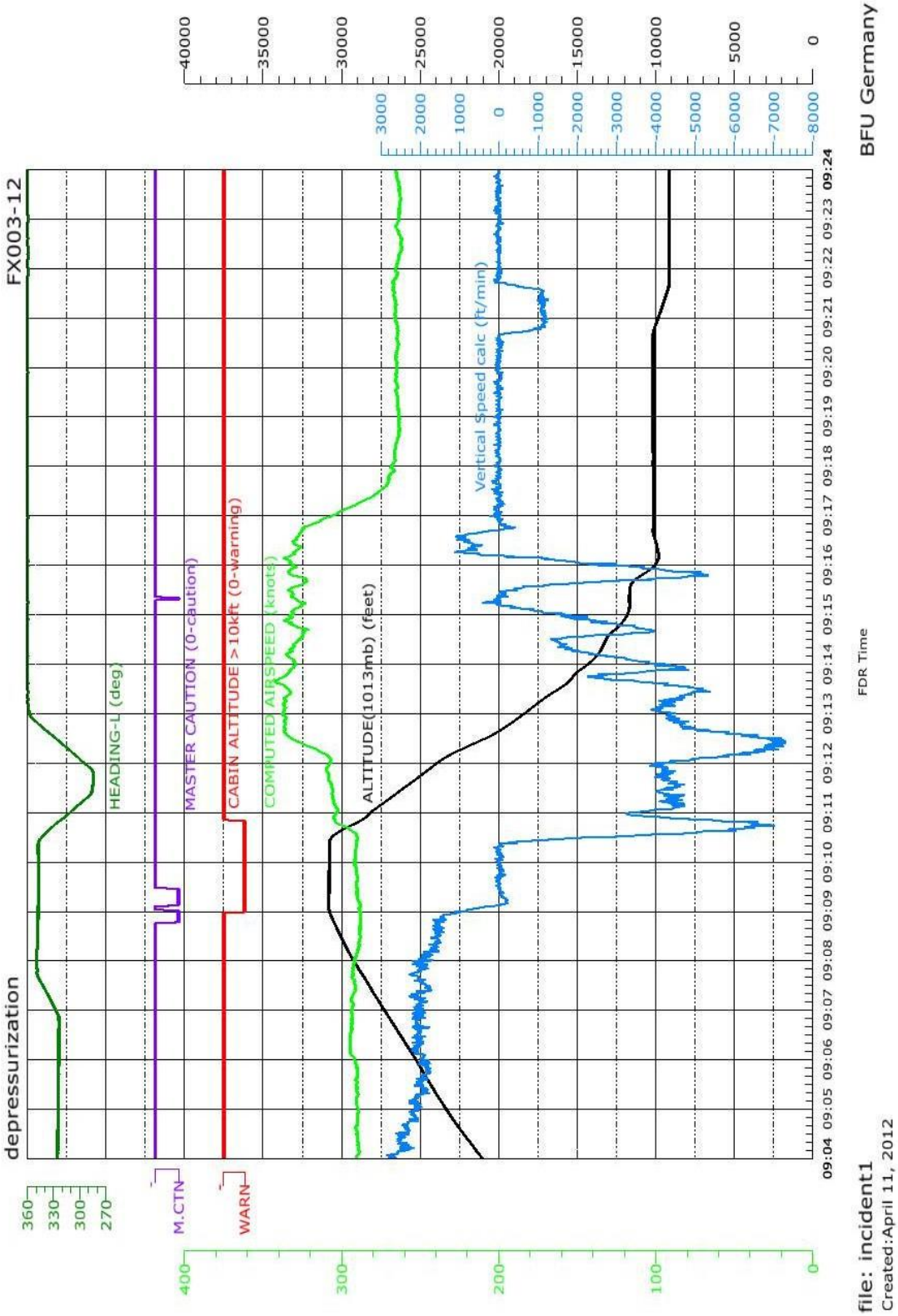
> Boeing defines the design requirements for the pressure controller on a Specification Control Drawing. There is a section of this drawing which outlines shipping requirements for the controller. Boeing has incorporated additional language requiring that shipping caps be yellow in color and have orange or yellow colored tags stating that the cap must be removed after installation of the controller.
>
> We also understand that the current vendor of the pressure controller, Nord-Micro has purged their supply of any black caps and has revised their internal drawings and maintenance manual material to require only yellow caps with yellow or orange tags.

Investigator in charge: Jens Friedemann

Braunschweig: 13 March 2015

Appendices

Excerpt FDR data


FX003-12
depressurization
HEADING-L (deg)
MASTER CAUTION (0-caution)
CABIN ALTITUDE >10kft (0-warning)
COMPUTED AIRSPEED (knots)
ALTITUDE(1013mb) (feet)
Vertical Speed calc (ft/min)
M.CTN
WARN
FDR Time
BFU Germany
file: incident1
Created:April 11, 2012
Revised:May 29, 2012

This investigation was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FlUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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