TRANSPORTATION SAFETY BUREAU

FINAL REPORT

2011-272-4P
SERIOUS AVIATION INCIDENT

Budapest (LHCC) FIR
23 November 2011

Boeing 737-800
HA-LOK

INTRODUCTION

The present investigation was carried out by the Transportation Safety Bureau of Hungary on the basis of

- 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 repealing Directive 94/56/EC
- Act XCVII of 1995 on aviation,
- Annex 13 identified in the Appendix of Act XLVI. of 2007 on the declaration of the annexes of the Convention on International Civil Aviation signed in Chicago on 7th December 1944,
- Act CLXXXIV of 2005 on the technical investigation of aviation, railway and marine accidents and incidents (hereinafter referred to as Kbvt.),
- MET Decree 123/2005 (XII. 29.) on the regulations of the technical investigation of aviation accidents, incidents and irregularities;
- In absence of other related regulation of the Kbvt., in accordance with Act CXL of 2004 on the general rules of administrative authority procedure and service

The Kbvt. and the MET Decree 123/2005 (XII. 29.) jointly serve the compliance with Directive 2003/42/EC of the European Parliament and of the Council of 13 June 2003 on occurrence reporting in civil aviation.

The competence of the Transportation Safety Bureau of Hungary is based on Government Decree 278/2006 (XII. 23.).

Under the aforementioned regulations

- The Transportation Safety Bureau of Hungary shall investigate the aviation accidents and the serious aviation incidents.
- The Transportation Safety Bureau of Hungary may investigate aviation incidents and irregularities which - in its judgement - would have resulted in accidents under other circumstances.
- The technical investigation is independent of any administrative, infringement or criminal procedures initiated in connection with the transport accident or incident.
- In addition to the aforementioned laws, throughout the technical investigation ICAO Doc 9756 and Doc 6920 Manual of Aircraft Accident Investigation is applicable.
- The present final report shall not be binding, nor shall an appeal be lodged against it.

No conflict of interest has arisen in connection with any member of the investigating committee. Persons participating in the technical investigation shall not act as experts in other procedures concerning the same case.

The IC shall safe keep the data having come to their knowledge in the course of the technical investigation. Furthermore the IC shall not be obliged to make the data – regarding which its owner could have refused the disclosure of the data pursuant to the relevant act – available to other authorities.

DEFINITIONS AND ABBREVIATIONS

EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FIR	Flight Information Region
FSD	Flight Safety Department
IC	Investigating Committee
ICAO	International Civil Aviation Organization
Kbvt.	Act CLXXXIV of 2005 on the technical investigation of aviation, railway and marine accidents and incidents
MET	Ministry of Economy and Transport (Gazdasági és Közlekedési Minisztérium)
NTA DA	National Transport Authority, Directorate for Air Transport
pack	units of the air conditioning system
PF	pilot flying
PM	pilot monitoring
TSB	Transportation Safety Bureau

The cabin of the aircraft with the deployed oxygen masks, after it has landed and the passengers have disembarked

BRIEF DESCRIPTION OF THE OCCURENCE

Occurrence category		Serious aviation incident
Aircraft	**Class**	Fixed wing aircraft
	Manufacturer	The Boeing Co.
	Type	737-800
	Registration	HA-LOK
	Operator	Malév Zrt.
Occurrence	**Date and time in local time**	23 Nov. 2011 16:21 LT
	Location	Budapest (LHCC) FIR

There was no injury and the aircraft was not damaged in the occurrence.

Reports and notifications

The occurrence was reported to the TSB officer on duty at 15:50, 23 November 2011 by the duty personnel of the Flight Safey Department of Malév Zrt.

The TSB officer on duty

– Informed the NTA AA officer on duty at 15:58, 23 November 2011.

Investigating committee

On 23 November 2011, the Director-General of TSB assigned the following investigating committee (hereinafter referred to as IC) to investigate the case:

Investigator-in-Charge	György HÁY	investigator
Member	Márk KOVÁCS	investigator
Member	Péter KIRÁLY	field investigator

During the course of investigation, the contractual relationship of Márk Kovács as a government officer ended.

Overview of the investigation process

The IC has obtained the documents of the personnel, the aircraft and the flight, the records of the flight data recorder and cockpit voice recorder from the operator; and the records of radio communication and the radar shots from HungaroControl. The IC also interviewed the flight crew and cabin crew. In order to create the medical report, the IC obtained the certificates related to the medical conditions and abilities of the pilot, and the results of the exams. For the sake of data protection, this report contains only an abridged version of the medical examiner's opinion.

A short summary of the occurrence

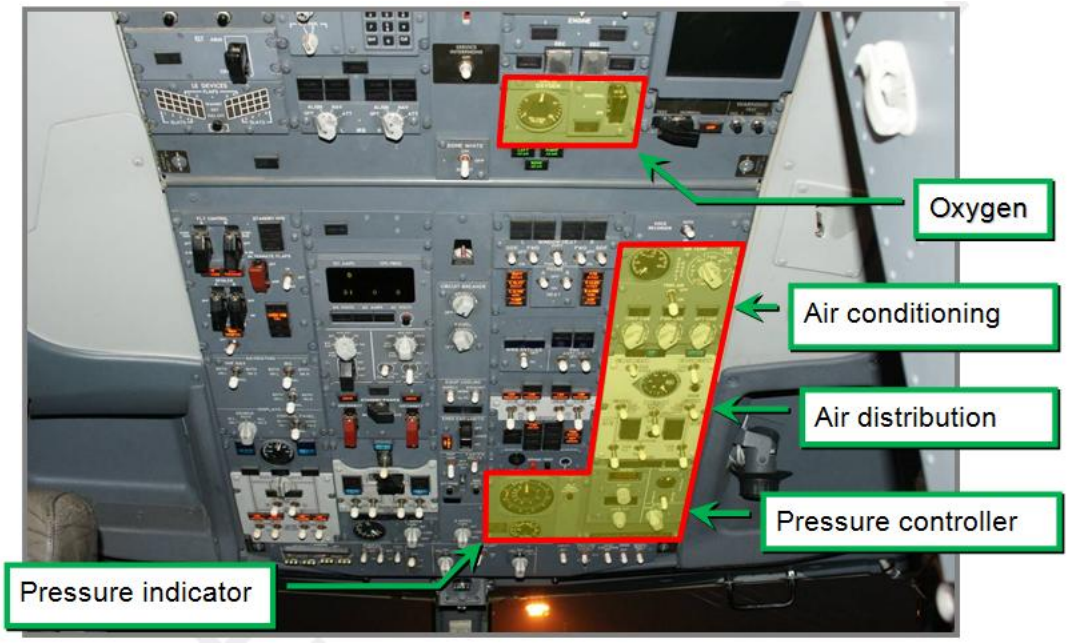
Having started the engine in Budapest, the personnel failed to turn on the "Pack" switches of the air conditioning system, thus air was not vented into the cockpit and into the cabin. During the climb after takeoff, approaching FL150, the cabin altitude horn went off as a result of excessive decrease in cabin pressure (reaching cabin altitude of 10 000 feet). In spite of this, the crew did neither turn on air conditioning nor carried out an emergency descent, thus cabin altitude kept on decreasing. Triggered by that, passing 14 000 feet cabin altitude, the oxygen masks were automatically deployed in the cabin. The crew turned around the aircraft and after a short wait above TPS[1], landed in Budapest. There were no personal injuries, but during the turn around, descent, approach and landing, the crew committed several mistakes which might have been provoked by the prior oxygen deficient period. TSB has formulated recommendations to be able to prevent and handle such events more safely in the future.

[1] „Tápiósáp" radio navigation aid.

1. FACTUAL INFORMATION

1.1 History of the flight

On the day of the occurrence, the crew reported to the execution of the scheduled flight MAH102/103 Budapest-Moscow-Budapest of Malév at the planned time, 14:20 LT. After the necessary preparations and having started the engines, they were cleared to taxi and started taxiing to runway 31L designated for takeoff. During lineup, they read out the "Before Takeoff Checklist" specified by the Malév Operation Manual and also displayed in the cockpit. As part of this procedure, regarding the air conditioning system and in line with the requirements, "**Packs: AUTO**" and "**Bleeds: ON**" was declared, meaning that cabin air conditioning is operative. After takeoff, carried out by the first officer, and conforming with the required procedure, the "After Takeoff Checklist" was also read out, in the course of which it was again confirmed that the switches of the cabin air conditioning system were in the appropriate position.

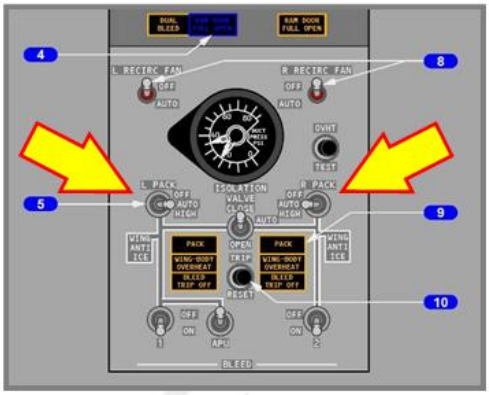


Panels of air conditioning, air distribution, pressure control and oxygen systems of the aircraft at the overhead control panel

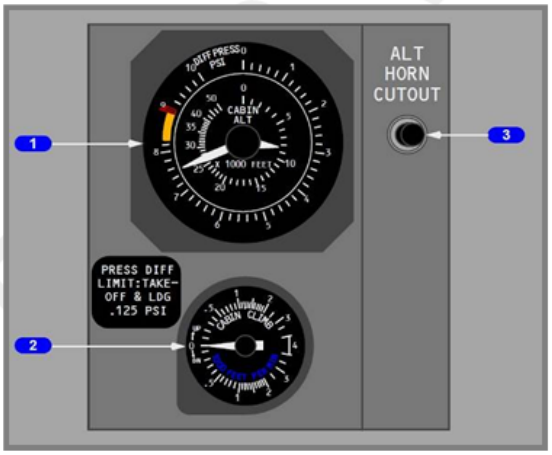
During climb, reaching 14 600 feet altitude, the discontinuous signal of the cabin altitude horn (hereafter referred to as "horn") indicating significantly low cabin pressure, i.e. too high "cabin altitude" (higher than 10 000 feet) went off. This was silenced by the commander using the switch off button after 30 seconds. One minute after the signal had begun to sound, the commander declared his decision to abort climb. The highest altitude was reached another 30 seconds later, at 17 250 feet. Via radio, the commander reported "technical trouble" to air traffic control and declared descending to FL140, and then further to FL120. The first officer deployed the speed brakes, and descending with an average vertical speed of 1750 feet/minute and an indicated air speed of 280-290 kts, they reached FL120 in 3 minutes (approx. 4 minutes after the horn going off).

Air distribution panel:

- ❺ ***Switches of the air conditioning system (indicated by the arrows)***
- ❽ ***Switches of the recirculation fans***
- ❹ ***and*** ❾ ***Displays***



When the horn went off and the climb of the aircraft was interrupted, the cabin altitude was still increasing with an average intensity of 2700 feet/minute (i.e. the pressure in the cabin was decreasing), and it reached 14 000 feet 90 seconds after the horn going off, leading to the automatic deployment of the oxygen masks in the cabin. During descent, in the fourth minute after the horn going off, the commander read out the „AUTO FAIL or Unscheduled Pressurization Change" Non-Normal Checklist. During this procedure he perceived, that the Air Conditioning Pack Switches are in the "off" position. As told by the commander, at this point he turned on the switches of air conditioning, and they continued their descent to FL120. Continuing flying at this altitude, the commander informed the passengers through the passenger address system that due to a technical problem they would return to Budapest. Then he asked clearance from air traffic control, and being granted that, 6 minutes after the horn going off, they headed back in the direction of VOR Tápiósáp.



Parts of the air pressure panel:

- ❶ ***Cabin altitude and differential pressure indicator***
- ❷ ***Cabin climb indicator showing the course and speed of pressure change***
- ❸ ***Horn off switch***

6.5 minutes after the horn going off and leaving FL120, they continued descent and 90 seconds later (in the 8th minute after the horn going off) FL100, i.e. an altitude of 10 000 feet, was reached.

With the permission of air traffic control, referring to the need of consuming their fuel surplus they navigated into holding position, and after flying one holding pattern, using radar directions they carried out an automatic ILS approach and a manual landing on runway 31R of Budapest Liszt Ferenc International Airport (LHBP). They started reading out the before landing checklist just 18 seconds prior reaching decision height, and finished it 4 seconds before that.

1.2 Personal injuries

Injuries	Crew		Passengers	Other
	Cockpit	Cabin		
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	2	4	70	

1.3 Damage to aircraft

There was no damage.

1.4 Other damage

The IC had not received any information on further damage by the completion of the investigation.

1.5 Information on the personnel

1.5.1 Data of the commander of the aircraft

Age, citizenship, gender		56 year old Hungarian man
Licence data	**Licence type**	ATPL
	Professional valid until	30/11/2012
	Medical valid until	02/10/2012
	Certificates	Commander
	Ratings	B737-300/900
Flying experience, hours/takeoffs	**Total**	17 482 hours / 11 154 takeoffs
	In the previous 90 days	217 hours / 113 take-offs
	In the previous 7 days	6 hours 51 minutes / 4 takeoffs
	In the previous 24 hours	2 hours 10 minutes / 2 takeoffs
	On the given type in total	2 072 hours / 1 066 takeoffs
Types flown		Tu-134, F70/100, B737-3/900
At the time of occurrence pilot flying / pilot monitoring		PM (was pilot monitoring)
Rest period / working time in the last 48 hours		43 hours rest / 5 hours in service
Date of last training		B737 retraining 23/05/2009
Date and results of the exams		Simulator, 07/10/2011 „Satisfactory”
The route concerned, knowledge and experience gathered of the relevant airports		Frequently flown route

Some years earlier, the commander, also then the commander, was involved in another serious aviation incident related to cabin pressure, which was investigated by TSB. During that investigation the IC established that[2]:

“Handling the situation, the crew deviated from the relevant specifications at several points.”

[2] Paragraph 3.1 of the final report of case No. 2007-491-4 TSB.

1.5.2 Data of the first officer

Age, citizenship, gender		56 year old Hungarian man
Licence data	**Licence type**	ATPL
	Professional valid until	31/10/2012
	Medical valid until	14/08/2012
	Certificates	First officer
	Ratings	B737-300/900
Flying experience, hours/takeoffs	**Total**	6 132 hours / 3 704 takeoffs
	In the previous 90 days	206 hours / 114 takeoffs
	In the previous 7 days	16 hours 05 minutes / 8 takeoffs
	In the previous 24 hours	3 hours 39 minutes / 2 takeoffs
	On the given type in total	3 032 hours / 1 587 takeoffs
Types flown		CRJ, B737-300/900
At the time of occurrence pilot flying / pilot monitoring		PF (was pilot flying)
Rest period / working time in the last 48 hours		37 hours rest/ 11 hours in service
Date of last training		B 737 31/01/2008
Date and results of the exams		Simulator 04/10/2011
The route concerned, knowledge and experience gathered of the relevant airports		Frequently flown route

1.6 Aircraft data

1.6.1. General

Class	Fixed wing aircraft
Manufacturer	The Boeing Co.
Type/subtype (type number)	737-800
Date of manufacturing	2004
Serial number	30669
Registration	HA-LOK
State of registry	The Republic of Hungary
Owner	International Lease Finance Co.
Operator	Malév Zrt.
Wet lessee	Malév Zrt.
Call sign at the given flight	MAH102

1.6.5 Loading data

Empty mass	42 470 kg	
Mass of fuel	13 900 kg	
Commercial load	7 976 kg	
Takeoff mass	**64 346** kg	
Flight mass at the time of the occurrence	63 500 kg	
Maximum allowed takeoff mass	71 708 kg	
Maximum allowed landing mass	**65 317** kg	
Center of gravity at takeoff	20.74	index
Center of gravity at the time of the occurrence	21.20	index
Allowed center of gravity positions	from 7.47 to 31.39	index

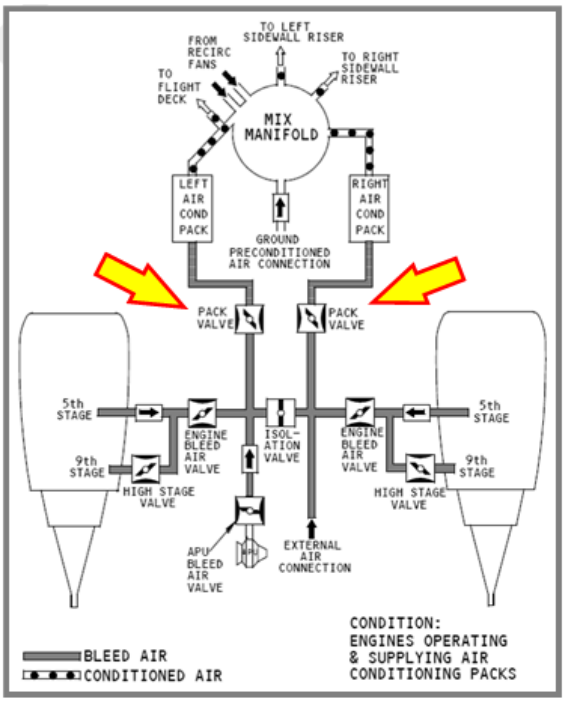
The aircraft's further parameters had no effect on the course of the events therefore they are not to be detailed.

1.6.6 Description of the systems concerned

Air conditioning

To stay alive, it is a basic requirement for humans to take up enough oxygen from ambient air, which is becoming more and more difficult with the decrease in air pressure. Thus, pressure in the cockpit and cabin of aircraft travelling at high altitudes[3] has to be kept at such a value, which is generally not lower than air pressure at 8 000 feet[4] height in the "normal" atmosphere; its concrete value depending on the flight altitude.

To maintain overpressurization, and counteract the inevitable loss due to leaks, air has to be continuously supplied into the aircraft. In the Boeing 737 aircraft this supply is provided by pressurized air bled from after the compressor stages[5] of the engines. The temperature of the air supplied into the cabin is regulated by the air conditioning equipment, by the right and left "packs". From the cockpit, air conditioning can be turned on and off by the "pack" switches, which open and close the valves[6] located in the way of the air streaming into the equipment.

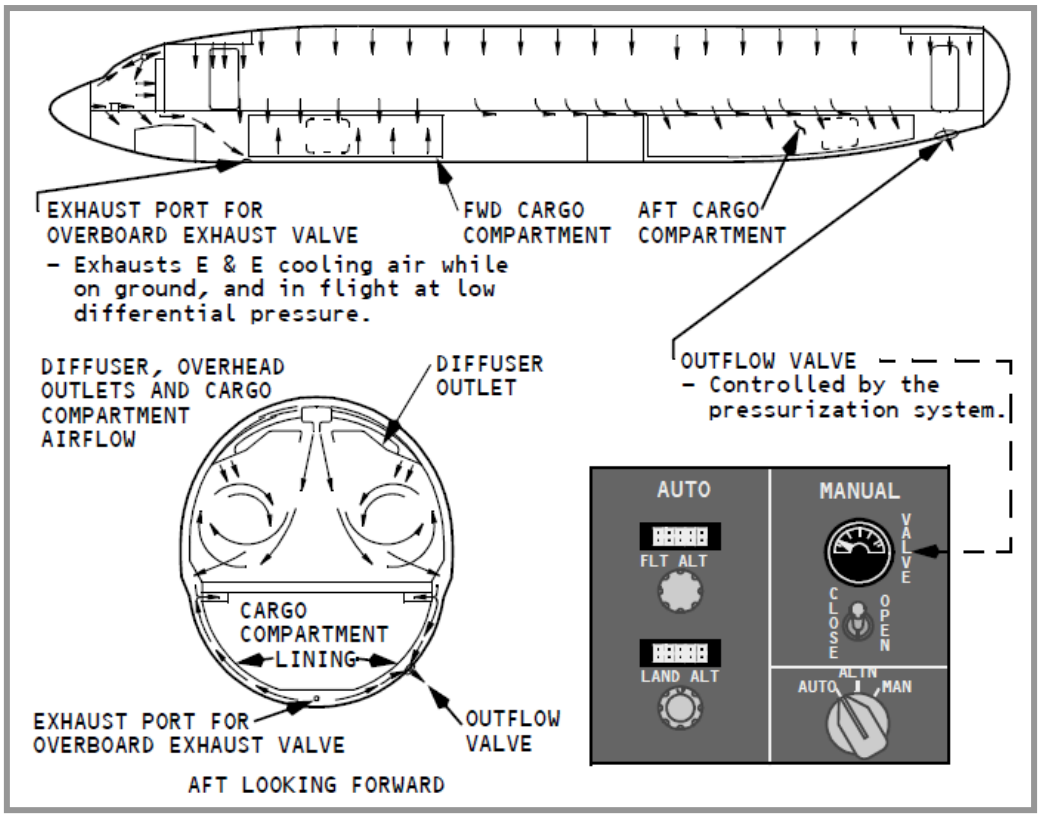


Draft of the air conditioning system (arrows indicate the on/off valves of air conditioning)

[3] above 3000 m, i. e. approx. above 10 000 feet
[4] 2500 m
[5] in some cases, from the APU, auxiliary power unit
[6] „Pack Valve" (indicated in the figure)

Cabin pressure control

The air pressure value in the cabin and cockpit of the aircraft is normally guaranteed by the automatic pressure control system which gradually opens and closes the outflow valve. Moving the outflow valve in the open position, outflow becomes more intensive, which in turn reduces cabin pressure, while closing the valve increases cabin presssure.



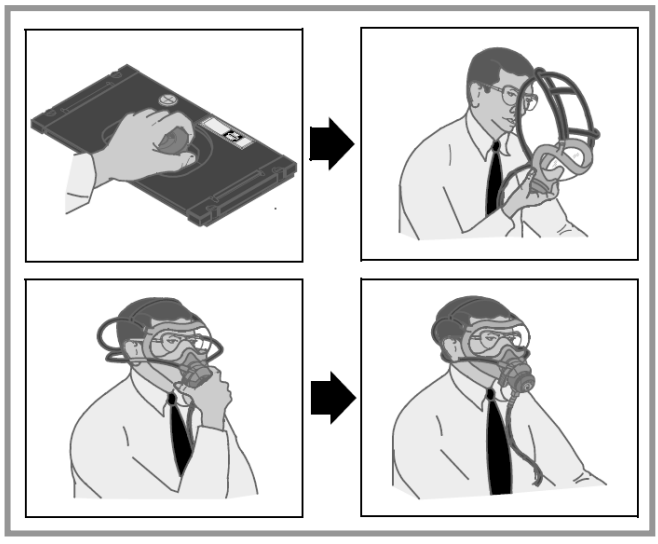
The operation of the cabin pressure control system with a parallel display of the control panel

Oxygen system

To cater for loss in cabin pressure, the aircraft has two separate oxygen systems, one for the personnel and one for the passengers.

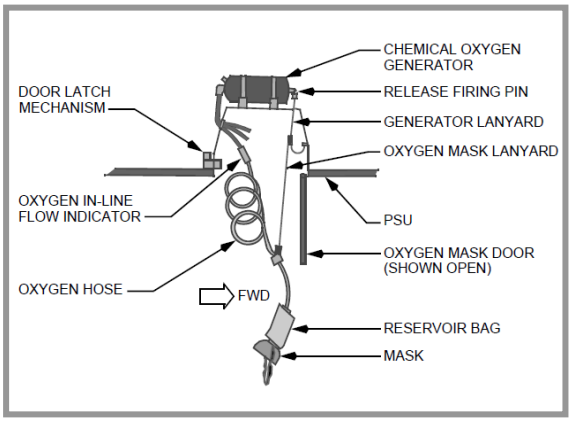
Oxygen system, cockpit

The oxygen masks of the crew, including smoke protection, are fed by a central, high pressure oxygen tank through a pressure regulator. The masks are designed and stored in such a way that putting them on will not even temporarily hinder the manual control of the aircraft.



The process of putting on the oxygen masks designed for the personnel

Oxygen system, cabin



The majority of the oxygen masks located in the cabin are provided with chemically generated oxygen supplied by the individual oxygen generators installed into the service units built in above the passenger seats.

The masks are deployed from their compartment in the service unit either triggered by the switch from the cockpit, or automatically by the pressure switch sensing cabin altitude, if it detects a “cabin altitude” higher than 14 000 feet. After this, the chemical oxygen generators begin to operate if at least one of the masks connected to them is pulled downwards. The generator having started to operate provides oxygen for approx. 12 minutes, and it cannot be stopped in this period.

1.6.7 On-board warning systems

The aircraft was equipped with the required warning systems, among others, with a cabin altitude warning horn (signalling cabin altitude above 10 000 feet), which was operative during the occurrence.

1.7 Meteorological data

The incident happened in daylight, by good visibility and without the presence of any noteworthy meteorological phenomenon. The meteorological conditions had no effect on the course of events, their analysis was not required.

1.8 Aids to navigation

The navigational instruments had no effect on the course of events therefore their analysis was not required.

1.9 Communication

The equipment recorded in the type certificate was installed onto the aircraft, the IC revealed no findings in connection with their operation or related to the ground based equipment and no irregularity was reported about them.

The commander did not declare either to have an urgent or an emergency situation to air traffic control, moreover, he confirmed that there is no need for the help of any special service.

1.10 Aerodrome information

The aircraft took off from Budapest Liszt Ferenc International Airport (LHBP) at 15:15, on 23 November 2011. Planned destination airport was Sheremetyevo, Moscow (UUEE). Landing occurred at LHBP airport, at 15:49.

The parameters of the aerodrome had no effect on the course of events therefore their analysis was not required.

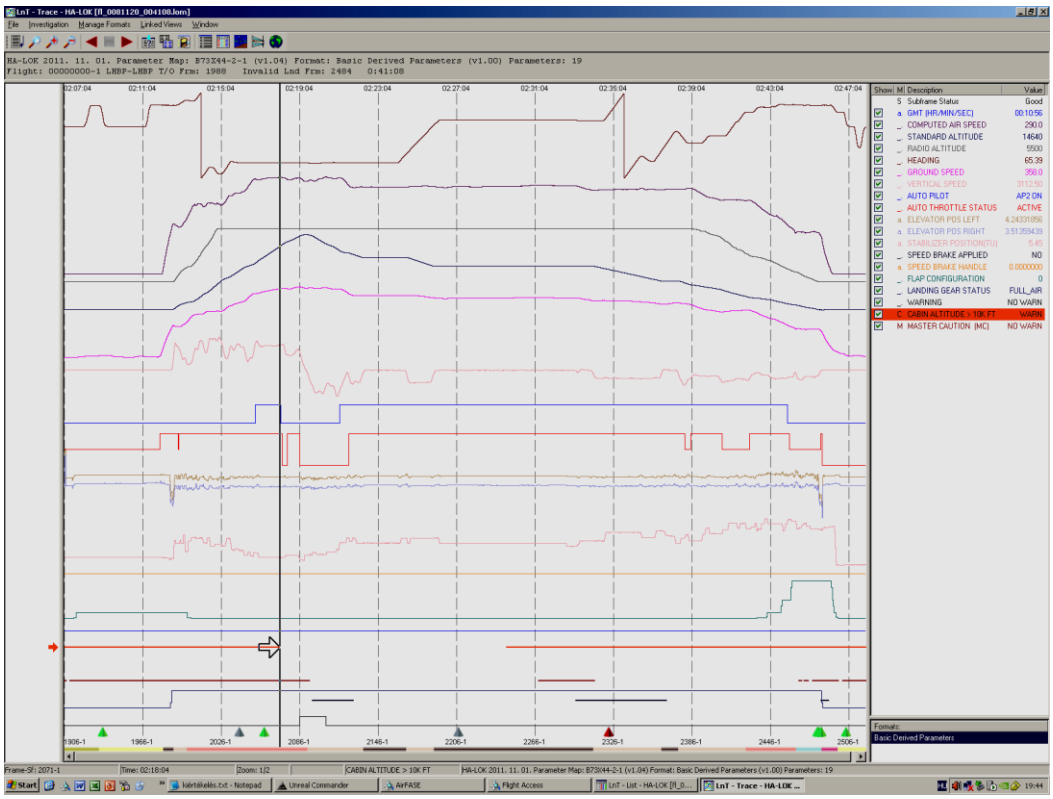
1.11 Flight recorders

Regarding the equipment of air traffic control and the aircraft, the required flight recorders were operative and the data recorded by them could be evaluated.

Flight data recorder	**Manufacturer**	HONEYWELL
	Type	980-4700-042
	Serial number	SSFDR - 05352
	Number of parameters recorded	8-900 depending on the build
	Location of data readout	Malév FSD
	Where and in what status it was located	HA-LOK

Cockpit voice recorder	**Manufacturer**	HONEYWELL
	Type	980-6022-001
	Serial number	06567
	Number of parameters recorded	4 channels
	Location of data readout	AEROPLEX
	Where and in what status it was located	HA-LOK

Reconstructing the sequence of events was made difficult by the fact that the flight data recorder does not record the instantaneous data of cabin pressure / cabin altitude.



Graphic display of all the relevant information recorded by the flight data recorder regarding the whole length of the flight

1.12 Wreckage and impact information

The incident did not result in a wreckage.

1.13 Data of the medical investigations

According to the section summarizing the opinion of the flight medical examiner:

Regarding the commander, the following could have contributed to the occurrence of the aviation incident:

- The change in his ability to concentrate and process information, the cause of which may be found in the permanent stress (social, at the workplace) indicated by the revealed antecedents.
- Hypoxic condition during one period of the flight.

Human factors contributing to the occurrence:

1. Fatigue (he also had a secondary employment).
2. Insufficient attention paid to equipment check.
3. Not using the appropriate checklist.
4. Faults in decision making (exaggerated self-confidence).
5. Breach of rules.

Comment:

After the aviation incident in 2007, the commander did not participate in an unscheduled flight medical exam and competency check.

Medical forensics examination

There was no medical forensics examination.

1.14 Fire

There was no fire.

1.15 Chances of survival

Information regarding personal injuries was not revealed to the IC during the course of investigation.

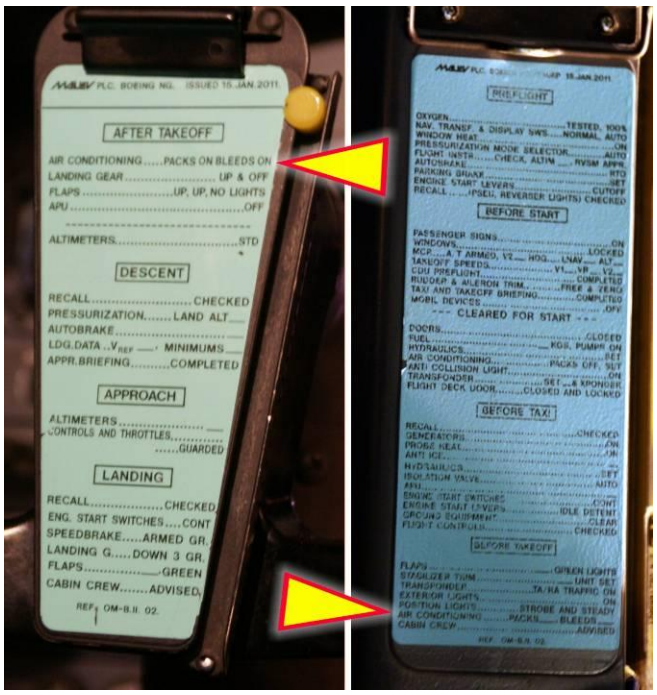
1.16 Tests and research

Tests and researches were not initiated by the IC.

1.17 Organisational and management information

1.17.1 Rules of normal and emergency handling of the air conditioning system

The procedures to be followed by the pilots at the time of the occurrence were specified, among others, by Version 15 of the Operation Manual, prepared by Malév Zrt. as based on EU-OPS 1.1045, and published on 26th July 2011, but approved by NTA AA only at a subsequent date, on 20th October 2011.

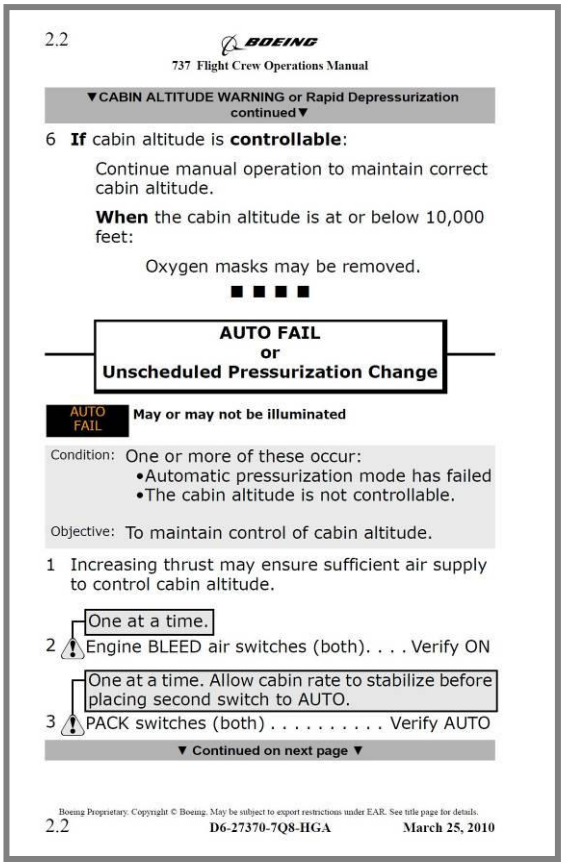


„Normal" checklists displayed in the cockpit (the line relevant to air conditioning are indicated in the before and after takeoff checklists)

According to the procedure laid down in paragraph 2.2.14 of Volume B of the Manual, after engine start, before beginning to taxi, at the command "*Before taxi procedure*" of the pilot occupying the left seat, the pilot seated in the right seat (in this case, the first officer) executes the procedure, during which he moves the air conditioning switches to the "AUTO" position. Before takeoff[7], again at the command of the pilot occupying the left seat and declaring "*Before takeoff checklist*", he reads out the "*Before Takeoff Checklist*" including also statements referring to the position of the air conditioning switches. These questions are answered by the commander.

After takeoff[8], the pilot not flying (in this case, the commander) executes the After Takeoff Procedure on his own initiative. Then, at the "*After takeoff checklist down to the line*" command of the pilot flying (in this case, the first officer), the pilot not flying (here the commander) reads out the "*After Takeoff Checklist*", also including a statement referring to the position of the air conditioning switches. He answers these questions himself. The texts of the checklists are also shown on the stickers displayed in the cockpit.

[7] having begun taxiing to the runway
[8] having retracted the flaps



2.2

BOEING

737 Flight Crew Operations Manual

▼CABIN ALTITUDE WARNING or Rapid Depressurization continued▼

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.

■ ■ ■ ■

AUTO FAIL or Unscheduled Pressurization Change

AUTO FAIL **May or may not be illuminated**

Condition: One or more of these occur:
- Automatic pressurization mode has failed
- The cabin altitude is not controllable.

Objective: To maintain control of cabin altitude.

1 Increasing thrust may ensure sufficient air supply to control cabin altitude.

One at a time.

2 Engine BLEED air switches (both). . . . Verify ON

One at a time. Allow cabin rate to stabilize before placing second switch to AUTO.

3 PACK switches (both) . . . . . Verify AUTO

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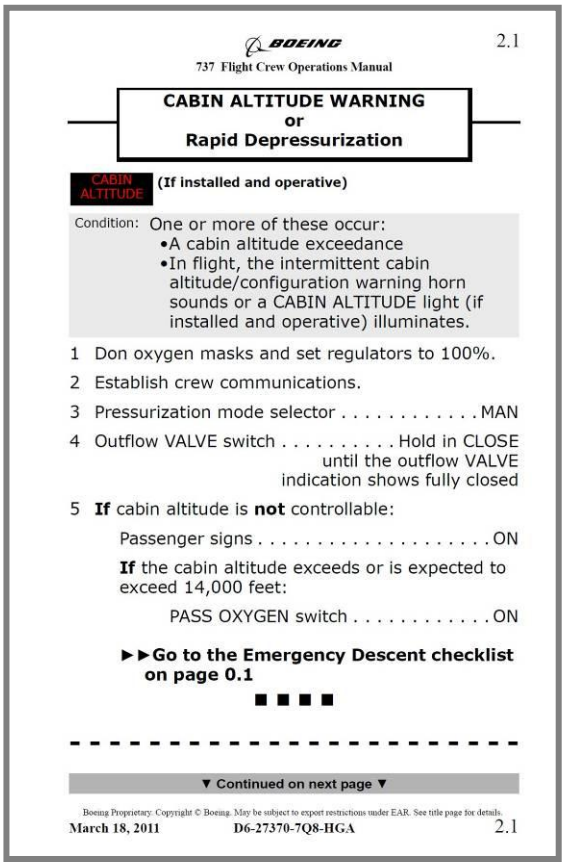

BOEING

2.1

737 Flight Crew Operations Manual

CABIN ALTITUDE WARNING or Rapid Depressurization

CABIN ALTITUDE **(If installed and operative)**

Condition: One or more of these occur:
- A cabin altitude exceedance
- In flight, the intermittent cabin altitude/configuration warning horn sounds or a CABIN ALTITUDE light (if installed and operative) illuminates.

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

■ ■ ■ ■

▼ Continued on next page ▼

Non-Normal Checklists applicable in case of loss of cabin pressure

The Quick Reference Handbook to be found in the cockpit includes the Non-Normal Checklists specifying in English the procedures applicable in emergency situations. According to these, if the pilots realize that the automatic cabin pressure control system is inoperative or cabin pressure is incontrollable due to other reasons, then they have to follow checklist "AUTO FAIL or Unscheduled Pressurization Change". The aim of this checklist is to regain control over cabin pressure. One of the first actions in the list is checking whether air conditioning is switched on.

However, if cabin pressure has already decreased so much[9] as to have triggered the warning signal[10], then checklist "CABIN ALTITUDE WARNING or Rapid Depressurization" has to be followed. The utmost aim of this is to keep the pilots safe and prevent them from harmful health effects. The first item on the checklist is requesting the pilots to put on their oxygen masks, and if cabin pressure cannot be restored by closing the outflow valve and flight altitude exceeds 14 000 feet, then it requires carrying out an emergency descent to 10 000 feet altitude which can be considered safe from point of view of air pressure (if this is rendered possible by the conditions of the terrain).

1.17.2 Alternative procedure applicable in certain cases of loss of cabin pressure

Several pilots flying a Boeing 737 have recited their experience, in which it happened on numerous occasions, that the air conditioning systems, having been switched off for engine start, were accidentally left in an off position. If this fault

[9] Cabin altitude has reached or passed 10 000 feet.
[10] „the horn".

was not recognized while reading out the checklists, then, during climb, the cabin pressure decreased until the warning horn sounded. It is not a standard, but a wide spread procedure, that climb is here interrupted, and before reading out the emergency checklist, the position of the air conditioning switches are quickly checked. If it is proven that the signal was caused by the air conditioning being switched off, then air conditioning is turned on without delay, and if cabin pressure begins to get restored (it increases), and the oxygen system of the passengers has not activated yet, then the flight is continued.

1.17.3 Flight medical examination of pilots concerned in aviation incidents where "the human factor" is involved

Point a) of paragraph 4(4) of the Joint Decree 14/2002. (II.26.) of the Ministry of Transport and Water Management and the Ministry of Health on the health requirements for personnel licensing in civil aviation lays down, that "*An unscheduled medical examination has to ascertain the aptness of the personnel after each aviation incident where human factors might have contributed to the occurrence*." The IC was unable to reveal any information indicating that after the serious aviation incident mentioned in paragraph 1.5.1 (that happened on 28 November 2007), the personnel, and among them, the commander involved in the present case as well, would have undergone such a kind of medical examination.

1.18 Additional information

Accident of the 737 of Helios Airways due to loss of cabin pressure

On 14th August 2005, at flight HCY522 (Larnaca – Athens – Prague) of Helios Airways, performed by the Boeing 737-300 aircraft registered 5B-DBY, at the night prior take-off a pressure check was carried out, after which the maintenance crew forgot to switch on the automatic cabin pressure control system, and this was not done by the cockpit crew either. Thus the outflow valve remained completely open. During climb after take-off, at 12 000 feet the cabin altitude horn went off, but the crew did not realize its meaning, and with autopilot on, they continued the climb. Due to the more and more severe lack of oxygen resulting from the gradual decrease in pressure, in the course of some minutes, the crew became gradually incapacitated and then, unconscious. The aircraft on autopilot continued to climb to the cruise altitude, flew the route, and, in line with its programming, entered the holding pattern above Athens, and followed it until the engines shut down due to running out of fuel. Then the aircraft crashed down, its crew of six and its 115 passengers lost their lives.

1.19 Useful or effective investigation techniques

The investigation did not require techniques differing from the traditional approach.

2. ANALYSIS

2.1 Failure to switch on air condition

In the present case, the first officer failed to turn on the “Pack” switches of air conditioning during the before taxi procedure, which have to be always switched off in the course of engine start, since it is the pressurized air which provides energy for the starting turbines to spin up the engines. Although the before and after take-off checklists were read out, some of the questions included were answered without the crew assuring the exact position of the levers and switches. Consequently, the crew was not aware of the air conditioning equipment being switched off.

Excerpts from the medical examination report:

Routine behaviour *is carried out without cognitive control. It is an activity built up by automatic senso-motoric behavioural patterns. As the level of cognitive control is very low in these situations, in case of visually controlled activities, humans are more just “looking than seeing”. Activities based on routine are characterized by the fact that they are built on the fixed sequence of elementary tasks. If it becomes necessary, the sequence carried out automatically (checking the position on the panel, in the present case). The position of the switch should be conveying a message. During the sequence carried out automatically, the first officer did not notice this position, he did not become aware of the message this position implies, thus, he did not switch it on.*

2.2 The process leading to too low cabin pressure

The cabin pressure control system was not able to keep cabin pressure at an appropriate level during climb, since due to the lack of air supply, nothing could counteract the loss of air pressure through the inevitable leaks. The cabin altitude followed the actual altitude with a 4-5000 ft delay due to the small outflow rate through leaks of the pressurized cabin. When the aircraft reached 14 600 feet altitude, cabin altitude attained the value corresponding to 10 000 feet, and the warning horn went off.

It might be ascribed to the pilots being surprised that it took them a further minute to “decode” the signal, and recognize the loss of cabin pressure, and then to decide to stop climbing, the execution of which took another 30 seconds. As a result, they climbed to 17 250 feet, and then, in line with the decision of the commander, they commenced a “normal” descent to reach FL140 (14 000 feet). Although the crew identified the loss of cabin pressure, they had not been able to recognize its reason, thus they could not terminate it. Despite aborting climb and beginning to descend, the aircraft was still overpressurized to some extent, so air continued to leak through the orifices of the aircraft, and cabin pressure kept on decreasing.

Consequently, 90 seconds after the horn having gone off (nearly parallel to the start of the descent) cabin pressure reached 14 000 feet, and triggered by the automatic pressure switch, the passenger oxygen masks got deployed in the passenger compartment. Thus, the very long interval (90 seconds) elapsed between the horn going off and the start of descent, contributed significantly to reaching a too high cabin altitude and the passenger oxygen masks becoming activated. During this interval, cabin altitude was increasing very rapidly (by 2700 feet/minute on average). After the deployment of the passengers’ oxygen masks, the cabin pressure still kept on decreasing as long as flight altitude surpassed cabin altitude. Presumably, the two altitudes levelled off between the altitudes of 15 000 to 16 000 feet, 2.5 minutes after the horn having gone off.

2.3 Choosing the applicable emergency checklist

In the fourth minute after the horn having gone off, the commander started to read out the „AUTO FAIL or Unscheduled Pressurization Change" Non-Normal Checklist. In the course of this, he observed that the air conditioning system is switched off. Although applying this checklist was proven to be effective in the given situation, it was not the proper choice as based on the Operation Manual. In the given situation, a different checklist, called „CABIN ALTITUDE WARNING or Rapid Depressurization" would have had to be applied, since the texts of the checklists indicate shortly the conditions of applicability as well. This clarifies that in case of the cabin altitude horn going off, the second checklist is applicable.

2.3 Weighing the activities of the crew against the applicable emergency checklist

The emergency checklist applicable in case of the cabin altitude sound alarm (horn) going off, warning about the dangerous increase in cabin altitude, that is, the too extensive cabin pressure reduction, specifies in detail the procedure to be followed as found appropriate by the aircraft manufacturers and operating organizations who had issued the checklist (and also as approved by the authorities concerned):

- As an immediate first step, it requires the pilots to put on their oxygen masks, in order to prevent them from incapacitation. In this case this did not happen, although the first officer took out his oxygen mask approximately 180 seconds after the horn going off for the first time; but the commander did not agree with his conduct, so finally he did not put it on.
- The next item on the checklist is to manually close the outflow valve, which did not take place either, since that, as a logical result of how the system operates, had been closed already, and the commander ensured this, as he himself recalls, by checking the instrument showing the position of the valve.
- According to the checklist, if cabin altitude cannot be controlled even after closing the outflow valve, and flight altitude surpasses 14 000 feet, then the pilots have to deploy the oxygen masks of the passengers by using the relevant switch in the cockpit, and then, have to carry out an emergency descent. None of these happened in the case investigated. Initially, the first officer started an intensive descent, but the commander did not agree with this either.
- In line with the checklist applicable to emergency descent, descent has to be continued until 10 000 feet, if the terrain renders this possible. In this case descent was not hindered by the terrain, however, the commander first requested clearance to descend only to 14 000 feet, then modified this to 12 000 feet, and reaching this, they stayed at 12 000 feet for several minutes, while cabin altitude was above the 10 000 feet "threshold of alarm".

2.4 "Alternative" procedure to handle cabin pressure loss due to the air conditioning system

Although the "alternative" procedure described in paragraph 1.17 differs from that stipulated by the checklist applicable for the case of the horn going off, and included in the Manual, the "alternative" has several advantages over the required procedure, while it does not significantly increase the risk involved in handling the situation.

By adhering word by word to the emergency checklists, checking the fact that the cabin air conditioning system is on, and to switch it on, if necessary is only possible if the drop in pressure is detected before the horn goes off. This is rarely probable in practice, because the crew is not warned about having forgotten to switch on air

conditioning by any warning light or sound until the horn goes off, and the initial loss in cabin pressure is difficult to be perceived directly, only by the senses.

It is in the primary interest of all those involved in air traffic that the execution of flight tasks are only interrupted by an emergency descent in justified cases. It may seem reasonable to change the relevant procedures to enable the application of the "alternative" procedure described in paragraph 1.17 in case of the cabin altitude horn going off. In this case, by checking the switches of air conditioning, and if necessary, by turning them on, as all this requires only some seconds, carrying out emergency descent can be avoided in situations when the cause of pressure drop (air conditioning being switched off) can be determined quickly and unambiguously, and the problem can be solved.

2.5 Safety risk of the case investigated

During the serious aviation incident being investigated, the crew of the aircraft did follow neither the procedure on the emergency checklist, nor the unwritten rule of the "alternative" procedure. For a significant period after the cabin altitude horn going off, they did not recognize the cause of the loss in pressure, thus, they were not able to tackle the problem. In spite of this, they did not use the oxygen masks either, nor did they carry out an emergency descent to quickly reach the safe altitude of 10 000 feet. As a consequence, they spent nearly 8 minutes in an oxygen deficient environment, where air pressure was lower than at 10 000 feet cabin altitude. This situation threatened the pilots with incapacitation, thus endangering the aircraft and the safety of all persons aboard.

Excerpts from the medical examination report:

ICAO Doc. 8984-AN/895 Manual of Civil Aviation Medicine:

- *„3 050 m (10 000 ft): After a period of time at this level, the more complex cerebral functions such as making mathematical computations begin to suffer. Night vision is also explicitly impaired. Flight crew members must use oxygen when the cabin pressure altitudes exceed this level.*
- *3650m (12 000 ft): All flight crew actively involved in flying must use oxygen!*
- *4 250 m (14 000 ft): All persons are impaired to a greater or lesser extent with respect to mental functions including intellectual and emotional changes.*
- *4450m (15 000 ft): All passengers are to be provided with oxygen, as above this altitude all persons are impaired."*

2.6 Errors during approach and landing

The pilots committed several professional mistakes, by returning, by carrying out the descent too late and too slowly, by executing the unjustified fuel consumption manoeuvre, by arranging the preparation for landing tardily and by reading out the before landing checklist too late. These errors may be partly attributed to the longer period of hypoxia having a negative influence on cognitive processes.

3. CONCLUSIONS

3.1 Factual findings

The cockpit crew had the necessary ratings and certificates at the time of the occurrence, and was also experienced enough for the execution of the given flight.

The aircraft was airworthy. It had a valid certificate of airworthiness. The mass and the mass distribution of the aircraft was inside the required limits. The aircraft was filled up with fuel of appropriate quality and quantity for the flight.

There is no proof indicating that any structure or system of the aircraft failed before the incident and this would have caused or contributed to the development of the occurrence.

Until the occurrence, the flight was carried out according to the flight plan and by good visibility conditions, in daylight.

No objections were found against air traffic control, the characteristics of the aerodrome or the activities of the handling crew.

The hypoxia experienced by the pilots may have contributed to the errors committed by them during the return, descent, approach and landing.

After the prior serious aviation incident, in which the presently investigated commander was concerned, the medical examination of the crew was not carried out, thus possible inadequacies, if any, may have remained hidden.

3.2 Causes of the incident

The technical investigation of the IC concluded that the incident happened due to the following provable reasons:

– After engine start, the crew failed to turn the “Pack” switches of the air conditioning system from the “OFF” position to the “AUTO” position.

– The failure to turn on air conditioning was also not recognized while reading out the checklists.

– When the horn indicating dangerously low cabin pressure went off, the crew did not recognize and eliminate the cause of pressure loss.

– The checklist applicable in case of the horn indicating dangerously low cabin pressure going off, does not include checking the air conditioning switches, and turning them on, if necessary.

– In spite of not having been able to eliminate the cause of the loss in pressure in the 3 minutes after the sound warning, the crew did not follow the procedure laid down in the emergency checklist applicable in case of the sound warning going off.

– The Final Report investigating the serious aviation incident of some years ago established that the activities of the crew led by the same commander swerved at several points from the relevant specifications.

– Following the earlier serious aviation incident, the commander did not undergo an unscheduled medical examination, thus his possible medical inadequacies which might have contributed to the occurrence may have remained hidden.

4. SAFETY RECOMMENDATION

4.1 Safety recommendations issued during the technical investigation

The IC did not reveal any circumstances which would have called for issuing immediate safety recommendations.

4.2 Safety recommendations issued during the conclusion of the technical investigation

As the conclusion of the technical investigation the IC recommends to issue the following safety recommendations:

BA2011-272-4P-1 *In the course of the investigation, the IC has found, that when the cabin altitude horn went off, the crew started reading out the checklist only after a very extensive (several minutes long) delay, an even then it was not carried out in adherence to the requirements. According to the information provided to the IC, in simulations, the cases of pressure drop are presented to the pilots frequently under identical, conventional conditions, which only helps indirectly in recognizing and coping with real-life cases.*

TSB recommends the Directorate for Air Transport of the National Transport Authority that it pay special attention to present, practice and test cases of cabin pressure loss under real-life conditions during the training and testing of commercial pilots.

As a result of the acceptance and execution of the recommendation the IC expects that in possible similar situations in the future the crew of the aircraft will handle the situation less belatedly, and in line with the requirements.

BA2011-272-4P-2 *In the course of the investigation, the IC has been provided with information stating that in the recent years the pilots of the Boeing 737 aircrafts several times failed to turn the "Pack" switches of air conditioning from the "OFF" to the "AUTO" position after the engine start, and they did not recognize this failure even during reading out the checklists. On several airplane types a neutrally coloured light (e.g. white) is used to indicate conditions not in line with the usual status.*

TSB recommends the Federal Aviation Administration and the European Aviation Safety Agency to consider using an alerting annunciation on the Boeing 737 aircraft, which would indicate to the pilots that air conditioning is not on.

As a result of accepting the recommendation, and applying the warning light, the IC believes that a decrease in the number of irregularities and serious incidents due to the inaccurate operation of air conditioning switches can be expected.

BA2011-272-4P-3 *The investigation would have been greatly facilitated, if the momentary value of the cabin pressure/cabin altitude had been known in the course of the event.*

TSB recommends the International Civil Aviation Organization to consider extending the data obligatorily recorded by the accident data recorder of the aircrafts to include the momentary value of cabin pressure.

As a result of accepting the recommendation, the IC expects that the occurrences related to cabin pressure can be investigated in a more efficient and effective way in the future, which will indirectly have a positive effect on flight safety as well.

BA2011-272-4P-4 *The IC has found, that the procedure to be followed in case of the warning sound indicating a drop in the cabin pressure going off on the Boeing 737 type does not give an opportunity to check whether air conditioning is turned on, and to switch it on, if necessary.*

TSB recommends the Federal Aviation Administration and the European Aviation Safety Agency to consider altering the flight manual of the Boeing 737 aircrafts in such a way, that in case of the warning sound indicating a drop in the cabin pressure going off, it becomes possible to check whether air conditioning is turned on, and to switch it on, if necessary.

As a result of accepting the recommendation and by changing the required procedure, the IC believes that emergency descents to be carried out by pilots could be avoided in those cases, when the problem can be quickly and safely solved by switching on the air conditioning.

Budapest, "27" February 2014.

György HÁY
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Péter KIRÁLY
Member of the IC

NOTE:
The present document is the translation of the Hungarian version of the final report. Although efforts have been made to translate it as accurately as possible, discrepancies may occur. In this case, the Hungarian is the authentic, official version.