Statens haverikommission
Swedish Accident Investigation Authority

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Serious incident involving the airplane LN-RPS on 4 April 2012 in the airspace east of Gävle, Gävleborg County, Sweden

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Statens haverikommission
Swedish Accident Investigation Authority

1. The Swedish Transport Agency, Maritime and Civil Aviation Department
2. European Aviation Safety Agency (EASA)
3. U.S Federal Aviation Safety Agency (FAA)

Final report RL 2013:03

The Swedish Accident Investigation Authority (Statens haverikommission, SHK) has investigated a serious incident that occurred on 4 April 2012 in the airspace east of Gävle, Gävleborg County, involving one aircraft with the registration LN-RPS.

In accordance with Section 14 of the Ordinance on the Investigation of Accidents (1990:717), the SHK investigation team herewith submits a final report on the results of the investigation.

The Swedish Accident Investigation Authority respectfully requests to receive, by 25 April 2013 at the latest, information regarding measures taken in response to the recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas   Staffan Jönsson

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring again, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?* SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation
The investigation of aviation incidents are governed by the Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation. The investigation is carried out in accordance with the Chicago Convention Annex 13.

The investigation

On 4 April 2012 SHK was informed that a serious incident involving one airplane with the registration LN-RPS had occurred at 09.50 hrs. that day in the airspace east of Gävle, Gävleborg County.

The incident has been investigated by SHK as represented by Mr Mikael Karanikas, Chairperson, Mr Staffan Jönsson, Investigator in Charge and Mr Nicolas Seger, Operations Investigator.

The investigation was followed by Mr Hans Winterstam of the Swedish Transport Agency, Civil Aviation Department.

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Airplane; registration and model	LN-RPS, Boeing 737-600
Class - Airworthiness	Normal - Certificate of Airworthiness and valid ARC
Owner - Operator	NBB Namsos Co. LTD - SAS Struktur Skand. KB, SAS (SK)
Time of occurrence	04-04-2012, 09.50 hrs. in daylight Note: All times are given in Swedish daylight saving time (UTC[1] + 2 hrs.)
Place	East of Gävle, Gävleborg County, (pos. N 60° 51' E 018° 32', 11,300 m above sea level)
Type of flight	Commercial air transport
Weather	According to the Swedish Meteorological and Hydrological Institute's (SMHI) analysis: winds NW 30-40 kts, good visibility, with no clouds above 6,000 metres
Persons on board:	
crew members	5
passengers	69
Injuries to persons	None
Damage to airplane	None
Other damage	None
Commander:	
Age, licence	52 years, ATPL (A)[2]
Co-pilot:	
Age, licence	41 years, CPL (A)[3]

History of the flight

The airplane performed a scheduled flight from Stockholm/Arlanda Airport to Skellefteå. An alternate landing site in the event of weather deterioration was Luleå/ Kallax. While climbing through Flight Level[4] 370, corresponding to an altitude of 11,300 m, the left “Bleed Trip Off” warning was activated. This system controls the engine bleed air for pressurisation of the cabin. The pilots took measures in accordance with QRH[5] point 2:6 in the event of “Bleed Trip Off” and continued the flight. About a minute later, the warning returned and the crew did not reset the warning, but shut off the system in accordance with QRH.

[1] UTC - Coordinated Universal Time, is a reference for the exact time anywhere in the world.
[2] ATPL (A) - Airline Transport Pilot License (Aeroplane) – is a license required to be able to fly as a commander in commercial air traffic with more than one pilot.
[3] CPL (A) - Commercial Pilot License (Aeroplane) – is a license required to be able to fly as a first officer in commercial air traffic with more than one pilot.
[4] FL- Flight Level, altitude with reference to standard atmospheric pressure (1,013.2 hPa) expressed in hundreds of feet.
[5] QRH – Quick Reference Handbook, contents include emergency checklist.

The aircraft continued to climb to Flight Level 410, during which time the pilots discussed the need to be able to descend quickly in the event that the remaining system also ceased to pressurise the cabin. Soon after the aircraft levelled out at the predetermined altitude, the right-side system activated a “Bleed Trip Off” warning. The crew declared an emergency and were given clearance to descend to Flight Level 100. Oxygen masks were put on in the cockpit and the aircraft reduced its altitude at a rapid rate of descent. The wings' speed brakes[6] were deployed. The commander initiated manual deployment of oxygen masks in the cabin. While the aircraft descended, the cabin altitude increased and the two met at 14,000 feet. During the rapid descent, the audible warning signal for the cabin altitude sounded, which is triggered when this exceeds 10,000 feet.

The weather en route was good and the crew initially decided based on fuel levels to land at the airport in Sundsvall, but as it was closed they instead chose the nearest open airport, which was Umeå. Following consultation with the cabin crew, who reported that all was well, the commander cancelled the emergency situation. The flight continued to the alternate destination at an altitude of 10,000 feet or 3,050 metres. Approach and landing at Umeå Airport were normal. After landing, the commander and other crew members carried out a debriefing with the passengers in the terminal building.

The engines' Bleed Air Systems

The regulatory system in the engines' Bleed Air Systems (see Fig. 1) consists of a number of pneumatic and electronic components controlled by analogue input.

Each engine has a Bleed Air System that, among other things, supplies the cabin with the correct pressure and the Air Conditioning System with air (bleed air). The bleed air issues from the engine's compressor via two Bleed Valves placed on the compressor housing at compression stages 5 and 9. The Bleed Valves at stage 9 are called High Stage Valves (HSV).

Before the bleed air is introduced into the Air Conditioning System, it must be cooled down and subjected to pressure regulation. This is done via a Pressure Regulating and Shutoff Valve (PRSOV), which is controlled by a pneumatic/electronic regulator called a Bleed Air Regulator. The Bleed Air Regulator receives its information from a number of pressure and temperature sensors in the system.

[6] Speed brakes - spoiler installed on the wing's topside and which increases drag when deployed

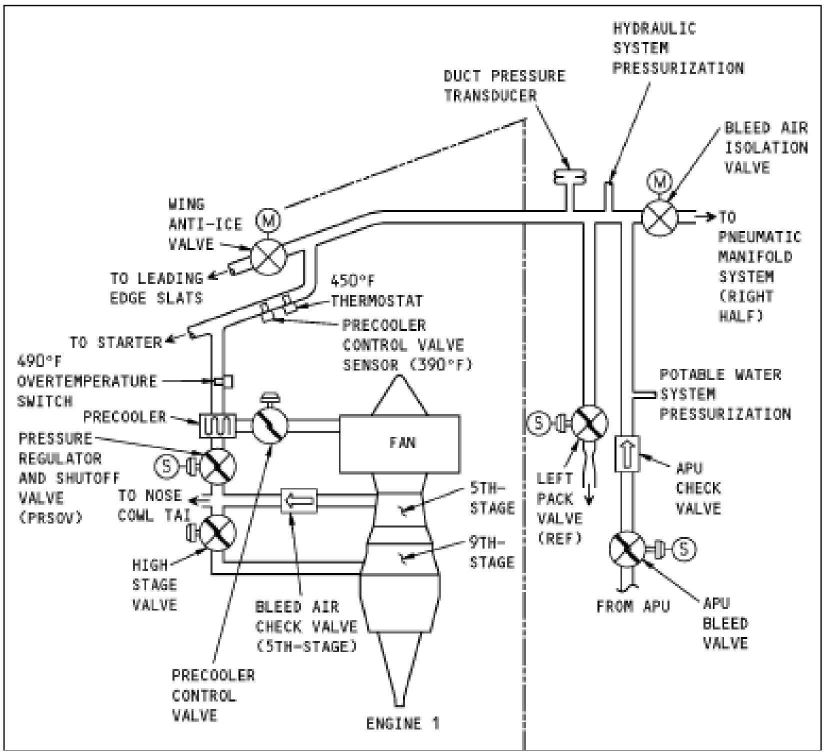

Fig. 1. Schematic of the Bleed Air System (left engine).

The Bleed Air Systems are controlled by the pilots via a control panel located in the overhead panel (see Fig. 2).

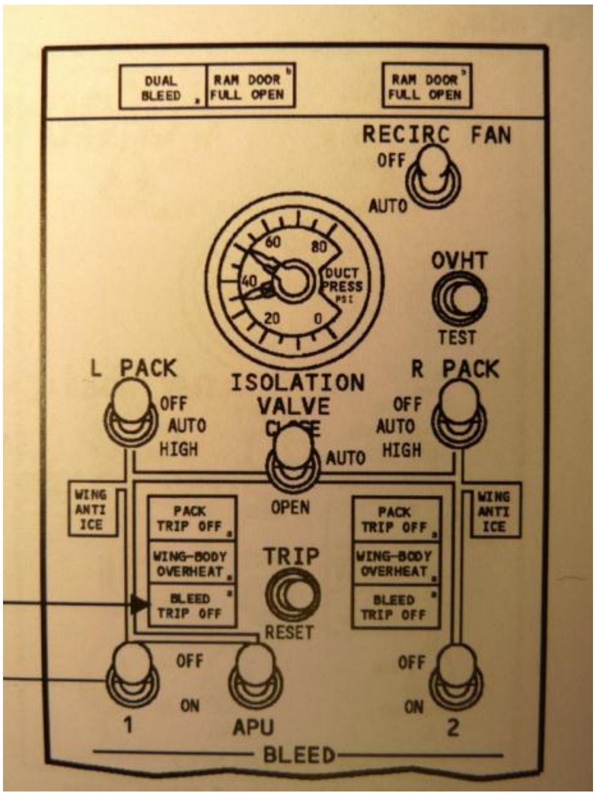

Fig. 2. Control panel for the Bleed Air Systems, Bleed module. (Photo: SHK).

The components of the Bleed Air System, most of which are located inside the engine cowling in each engine nacelle, have no set operating time limits and may be in operation as long as they function normally.

Bleed Air System - fault history

The fleet of this aircraft model has over the years been affected by a number of disturbances in the Bleed Air System. In many cases, the faults have been of an intermittent nature, and have therefore been difficult to isolate and rectify.

The Type Certificate Holder has together with the OEM[7] (Honeywell) drawn up specific instructions to facilitate fault isolation of the Bleed Air System, which have been incorporated in the Fault Isolation Manual (FIM) for the aircraft model.

Several modifications have been made to some of the system's components, but according to the operator, the MTBF[8] of components in the system is still high.

The PCCV[9], which controls the cooling air through the pre cooler, will according to available information appear in a modified design in the fourth quarter of 2012.

The operator states that the number of faults in components under ATA codes[10] 21 and 36 has increased since the introduction of amended approach procedures at certain airports. The main difference nowadays is that flights take place for a longer period, with moderate thrust on the engines, thereby generating vibration levels that previously were normally exceeded transiently.

It should be noted that in accordance with the MSG-3[11] analysis in which faults in the Bleed Air System are evaluated, this is not classed as safety-related for this model of aircraft, even if the fault leads to emergency descent.

The operator's measures

For the purpose of prevention, the operator has on its own initiative introduced a special periodic check of the system's functionality, in order to detect and rectify any defects before faults occur during operation. The evaluation of this activity has revealed that the updates to components susceptible to disturbances as recommended by the manufacturer, Honeywell, have not increased the time between failures.

At the turn of the year 2011/2012, the operator introduced an updated periodic check of the Bleed Air System in order to ensure that each part of the systems is able to withstand the stipulated pressure. The test was carried out in order to verify that a single system can produce the cabin altitudes required when the aircraft has been approved for flight in accordance with MEL chapter 21-01, with only one Air Conditioning System operational. The check is performed at a frequency of less than two years.

Based on this occurrence the operator has made a decision to add a functional test on the PCCV and TAI and its solenoids. The test is performed on the B-Check[12].

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[7] OEM - Original Equipment Manufacturer – Manufacturer of the original equipment.
[8] MTBF - Mean Time Between Failure.
[9] PCCV - Precooler Control Valve.
[10] ATA codes – Division of components into subgroups according to physical function.
[11] MSG-3 – Maintenance Steering Group – deals with the maintenance of large aircraft.
[12] B-Check – Major overhaul, scheduled about yearly.

Air Conditioning Systems

The aircraft model is equipped with two separate Air Conditioning Systems, which supply the cabin with air for ventilation and pressurisation. The systems also regulate the temperature and humidity of the cabin air.

In the Air Conditioning Systems, outside air and recirculating cabin air are mixed with heated air under high pressure from the aircraft's engines (bleed air) and pressurise the cabin after pressure and temperature regulation. The switch for each Air Conditioning System has three positions; “OFF”, “AUTO” and “HIGH”. According to the checklist, the switches are to be set to the “AUTO” position prior to flight.

According to the flight manual, each engine's Bleed Air System has the capacity to maintain an air pressure in the cabin equivalent to an altitude of approximately 7,000 feet (approximately 2,100 m) above sea level if the system is set in the “HIGH” position. A cabin altitude of approximately 7,000 feet or lower is generally considered to be comfortable from a passenger viewpoint.

With only one functioning Bleed Air System and Air Conditioning System and the switch in the “AUTO” position, the capacity is not sufficient to maintain the cabin altitude of 7,000 feet at the maximum flight altitude; the pressure decreases due to the air circulation and normal leakage in the pressurised cabin.

The system’s design includes a built-in redundancy. In the event of a “Bleed Trip Off”, the following occurs, provided that the Isolation valve is in the “AUTO” position:

Following the QRH, when the crew selects the affected side’s air conditioning pack to the “OFF” position (see Figure 2), the operating pack will automatically switch to HIGH flow and the isolation valve will open. In this configuration, the remaining engine bleed will supply pressurized air to the airplane as well as supply wing anti-ice bleed air to both wings as necessary during the descent.

In the incident under investigation by SHK, both the right- and left-side bleed systems became non-operational.

Warning system[13] and procedures in the cockpit

The most important systems and functions in the aircraft from a flight safety perspective are monitored by a warning system. Warnings are issued at two levels of priorities. Warning items requiring immediate crew knowledge and action have a “Master Warning”[14] red light and an associated aural alert. Items which require crew timely attention only are in the form of a “Master Caution[15]”amber light and associated separate light in an annunciator panel indicating which system is affected (see Figure 3). The annunciator panel is located on the instrument panel's glare shield (see Figure 4).

[13] Nomenclature conforms to SAS 737 Flight Crew Operating Manual.
[14] Master Warning – Primary warning signal with sound and text on a red background.
[15] Master Caution – Secondary warning signal with sound and text on an amber background.

The text on the annunciator panel indicator light shows which system that has triggered the warning. The pilots' respective annunciator panels monitor different systems, and a certain error will be displayed on only one of the panels, either in front of the left or the right pilot. The pilots must acknowledge warning messages by pressing the lightened button in the annunciator panel, which is spring-loaded and is able to move a few millimetres inwards from its neutral position. The warning light is then extinguished, but it can be brought back via a repeated press of the panel. Acknowledgement of a warning resets the Master Caution System, so that any new malfunctions can be displayed.

For certain faults, a sign also illuminates by the control panel for the system experiencing a fault.

Fig. 3. Master caution system panel on the instrument panel in front of the left pilot. (Photo: SHK)

When a warning arises, the normal procedure is for one of the pilots to call out “Master Warning” or “Master Caution”. This must be confirmed by the other pilot, after which the warning is acknowledged by means of pressing on the annunciator panel. Thereafter, measures are taken in accordance with the checklist for the faulty system.

Fig. 4. Instrument panel in Boeing 737-600. (Photo: SHK)

Measures in the event of loss of cabin pressure

In the event of a loss of cabin pressure at high altitude, the flight altitude must be reduced immediately. The crew requests to be allowed to descend to a safe altitude, normally 10,000 feet (3,050 m). Air traffic control then clears the aircraft for the requested altitude. At the same time, the crew puts on oxygen masks and ensures that leaving that flight altitude entails no risk of collision.

The Rapid Decompression and Emergency Descent Checklist shows how such a manoeuvre is carried out. The most important points for action in the list are to be carried out by the pilots from memory “by heart items” and checked against the checklist. Adjusting the switch for the Air Conditioning System is not one of these memory points.

If the cabin pressure decreases to an altitude corresponding to 10,000 feet (3,050 m), a warning illuminates on the instrument panel in front of the pilots and an intermittent audible signal sounds. Should the cabin pressure fall below the equivalent of an altitude of 14,000 feet (approximately 4,300 m), oxygen masks are automatically deployed for the passengers in the cabin and a warning text pertaining to this is displayed on the instrument panel in the cockpit. The passengers' oxygen masks can also be deployed manually by the crew.

Fault isolation following the incident

The technicians that commenced the fault isolation on the aircraft's systems established upon physical checks of the left engine components that the HSV[16] was in a half-open position. It should have been closed. They also noted that the shaft for the control valve, PCCV, showed signs of extensive wear. Both of these units were replaced. For identification of units, see Figure 1.

The technicians found that the aforementioned units needed to be replaced on both the left and right engines. They also noted on the right side that the damper for the control valve, PCCV, could be turned freely; see Figure 6. Both of these units were replaced. In addition, the control valve for the high-pressure bleed air, HSR[17], on the right side required adjustment.

Following a replaced components leak check during engine run, it was established that both left- and right-side systems were functioning without remark.

Faults in inspected components

Both the HSV and PCCV on the left and right sides, as well as the HSR on the right side, have been to the component workshop for rectification, whereby the faults could be verified.

On the HSV, the wear was particularly extensive and the shafts and links have worn in a manner that maintenance workshops had not seen previously on components with the equivalent operating time, see Figures 5 and 6. On the HSV seal there was also a black deposit - a “Rub strip” - that is probably a result of running in the engine's compressor, when the compressor's blade tips come into contact with the seal made with the compressor housing. The deposit is then pressed out via the bleed air ports in the compressor housing and adheres to the valve's sealing surface.

When checking the high-pressure bleed air, HSR, the valve did not provide regulation within established limits. After adjustment of the regulator function, the unit could be declared approved for use.

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[16] HSV - High Stage Valve, Bleed Air stage 9 of the compressor.
[17] HSR - High Stage Regulator, valve that controls HSV.

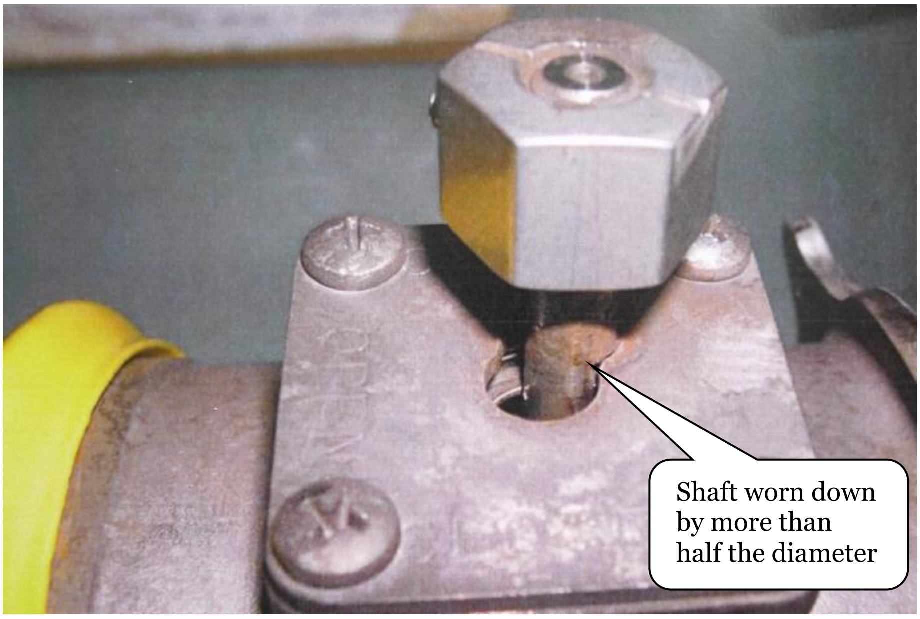

Fig. 5. The input shaft in the High Stage Valve (HSV), right-side engine. (Photo: SAS)

Handling a fault in the event of loss of one cabin pressurisation system

In MMEL[18] point 21-01, the operational altitude is limited to Flight Level 250 when only one system is operational. The information that only one system is operational is in most cases available prior to commencement of the flight. In cases where one of the original two systems fails during a flight in progress, the flight altitude is **not** limited in 737 NG QRH – NNC[19] "Bleed Trip Off" to Flight Level 250.

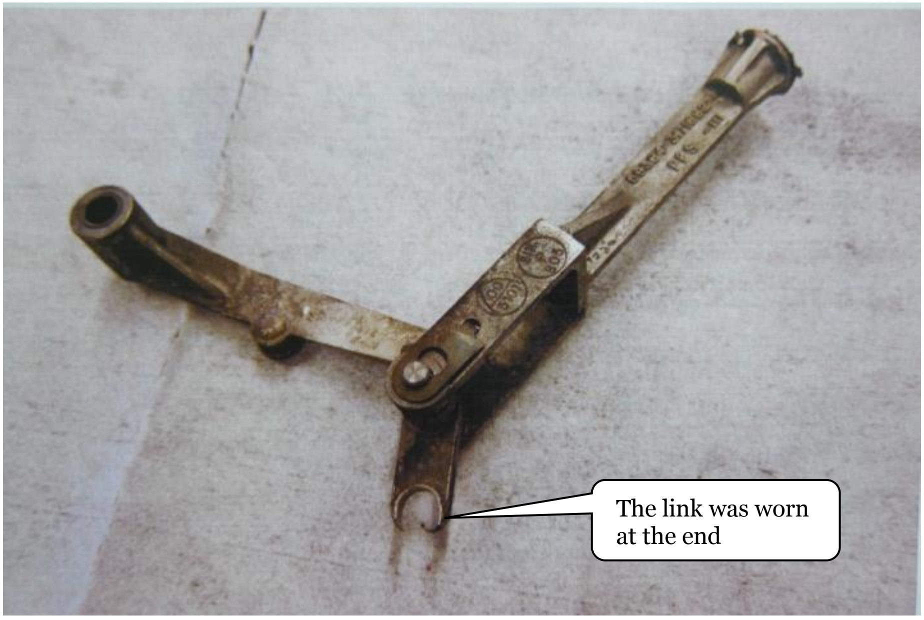

Fig. 6. The link system in the High Stage Valve (HSV), right-side engine. (Photo: SAS)

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[18] MMEL – Master Minimum Equipment List – Type Certificate Holder's list of equipment on board an aircraft that affects airworthiness and that under certain circumstances is allowed to be non-operational.

[19] NNC – Non Normal Checklist, emergency checklist is a part of this checklist.

Measures taken by authorities

A number of events resulting in serious incidents and accidents are associated with Boeing 737s and their cabin pressure systems. The difference between the 737 and the 737 NG in terms of the build of the systems is small. The most serious incidents have been as a result of lack or misinterpretation of indication and displaying of malfunctions in the cabin pressurisation system[20]. The types of fault that occurred in the incident that SHK is investigating in this case resulted in both systems going down in rapid succession. The parts that were non-operational were mechanical components and there was no clear connection to previously known serious incidents.

The FAA[21] is the supervisory authority for the Type Certificate Holder “The Boeing Company” and regularly follows how the 737 aircraft performs in service. It has been established that it is mainly mechanical components under the ATA 21 and 36 systems on the 737 NG that have a relatively high incidence of faults. Following an incident involving an aircraft in which the system monitoring of the cabin altitude did not function in the intended manner, the FAA urged Boeing to develop an Alert Service Bulletin[22] that improves the redundancy for the detection and presentation (ATA 31) of faults in the cabin pressure system.

The FAA has issued an AD[23] with the number 2012-19-11 that introduces the requirement for this bulletin from Boeing to be implemented in aircraft that are on the US register. The European Aviation Safety Agency, EASA, has evaluated the airworthiness directive issued by FAA and agreed that it should be applied from 7 November 2012. The requirement of implementing the bulletin is thereby applicable to airplanes registered in the European Union.

Conclusions

The assessment made by the crew when the climb had to be aborted was in line with the company's procedures. The flight altitude could be reduced without disruptions or delays and stabilised at Flight Level 100. The oxygen masks in the cabin were activated manually. The commander carried out a debriefing with the crew and passengers after landing. The persons that had experienced discomfort in connection with the flight received help in dealing with their impressions and experiences.

Since the introduction of this aircraft model in the late nineties, the Type Certificate Holder, Boeing, has carried out a number of controlled introductions of improved components, but the result of this work has not extended the operating time before a failure has occurred.

The operator's maintenance measures have changed following similar incidents in the past; a checking procedure has been introduced. In the event that one of the Bleed Air Systems is non-operational, checks are made to ensure that the remaining system has the capacity to maintain the cabin pressure during flight

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[20] For example Helios accident 11 Aug 2005, AIR ACCIDENT INVESTIGATION & AVIATION SAFETY BOARD (AAIASB) 11 / 2006

[21] FAA – Federal Aviation Administration, National Aviation Authority in the USA.

[22] Alert Service Bulletin – The Type Certificate Holder's mandatory instruction for modification/amendment of the aircraft.

[23] AD – Airworthiness Directive

up to Flight Level 250. The occurrence discussed in this investigation has resulted in implementation of functional tests on mentioned components on B-Check.

The FAA's airworthiness directive to modify the detection and presentation (ATA 31) of malfunctions in the pressurisation system is a sign that the design still has a high fault incidence and requires improvement.

SHK believes that the limitation introduced for application when flying with one Air Conditioning System inoperative, in accordance with MMEL 21-01, in which the operating altitude is limited to Flight Level 250, also should be taken into consideration when one system becomes non-operational during a flight in progress.

The incident was caused by the remaining cabin pressurisation system not being able to pressurise the cabin at the altitude where the airplane operated.

Recommendations

EASA and the FAA are recommended to:

Act to change the Boeing B737 QRH – NNC “Bleed Trip Off” so that a limitation of the flight altitude should be taken into consideration in the event of failure of one pressurisation system during flight in the same way as when this is identified before dispatch (Cf. MMEL point 21-01).
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