Depressurization in Cruise, Aer Lingus Boeing 737-500, EI-CDD, north of Paris, December 9, 2000

Micro-summary: **Mechanical failures result in a pressurization failure on this Boeing 737-500.**

Event Date: **2000-12-09 at 1345 UTC**

Investigative Body: **Air Accident Investigation Unit (AAIU), Ireland**

Investigative Body's Web Site: **http://www.aaiu.ie/**

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FINAL REPORT

AAIU Synoptic Report No. 2003-012
AAIU File No. 2000/065
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In accordance with the provisions of S.I. 205 of 1997, the Chief Inspector of Accidents, on 11 December 2000, appointed Mr. Jurgen Whyte, Inspector of Accidents, as Investigator-in-Charge to conduct a Field Investigation into this occurrence and prepare a Synoptic Report.

Aircraft Type and Registration:	Boeing 737-500, EI-CDD
No. and Type of Engines:	2 x CFM 56-3B1
Aircraft Serial Number:	24989
Year of Manufacture:	1991
Date and Time (UTC):	9 December 2000 at 13.45 hrs
Location:	North of Paris, FL 370
Type of Flight:	Public Transport, (Scheduled)
Persons on Board:	Crew 6 Passengers 92
Injuries:	Crew Nil Passengers Nil
Nature of Damage:	Nil.
Commanders Licence:	ATPL
Commanders Age:	39 years
Commanders Flying Experience:	8,724 hours
Information Source:	The Operator/Pilot Reporting Form/AAIU enquiries.

SYNOPSIS

While cruising north of Paris at FL 370, the aircraft experienced a pressurisation failure. After declaring a "MAYDAY", the crew carried out an emergency descent to FL 100. Diverting to Charles de Gaulle (LFPG) Paris, the aircraft landed at 14.20 hrs without further incident. There were no reported injuries to crew or passengers.

NOTIFICATION

The Operator notified the AAIU of this occurrence on the day of the incident.

FINAL REPORT

INTRODUCTION

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft (EI-CDD), with a crew of six and 92 passengers (including one minor) on board, took-off from Dublin (EIDW) at 12.50 hrs on the 9 December 2000 on a scheduled public transport flight to Rome (LIRF). The First Officer was designated as the Pilot-Flying (PF).

Cruising just north of Paris at FL 370, the first indication of a problem was when the Captain sensed a change of pressure in his ears. On checking the pressurisation system, the Captain observed that the cabin rate of climb was rising in excess of 1,500 ft/min and the differential pressure was at 6.9 pounds per square inch (p.s.i.). Shortly thereafter (13.45 hrs), the "MASTER CAUTION" and the "AUTO FAIL" warning light on the pressurisation panel illuminated. The crew immediately reselected the pressurisation system to "STANDBY MODE" and set 8,000 ft in the CAB ALT window. With the cabin rate of climb indicator still showing in excess of 1,500 ft/min, the crew switched to "MANUAL MODE", however, the cabin continued to climb. As a result of this, the Captain told the PF to prepare for an emergency descent and to go on oxygen. The crew having both donned their oxygen masks requested descent from Air Traffic Control (ATC) and actioned the "EMERGENCY DESCENT" drill from recall. The passenger oxygen masks were deployed in accordance with the emergency descent checklist. The request for emergency descent was not initially fully understood by French ATC, as only FL 350 was offered. The Captain then declared a "MAYDAY," which prompted ATC to immediately provide an emergency descent clearance to FL 100. In or around this time, the Captain recalls that the cabin altitude warning horn sounded.

On reaching FL 100, the crew confirmed their recall drills from the Quick Reference Handbook (QRH), briefed the Senior Cabin Crew Member (SCCM) and carried out a P.A. to the passengers explaining the situation.

Satisfied that the situation was under control, the Captain downgraded the "MAY DAY" to a "PAN", and requested a direct routing to LFPG. With an initial clearance given direct to Merue, the First Officer, now acting as Pilot-not-flying (PNF) made a request for radar vectors. The aircraft continued on radar vectors to LFPG. Mindful of possible discomfort experienced by the passengers during the emergency descent, the First Officer requested ATC to have medical personnel on standby on arrival. A gentle 500ft/min descent was carried out to LFPG, where the aircraft landed on Runway 27 at 14.20 hrs without further incident.

Later on the ground, the Captain was informed by a cabin crew member, that two loud bangs had been heard below the floor near the rear right hand side door. At 18.40 hrs, a replacement aircraft and crew arrived at LFPG from EIDW. All 92 original passengers took the option of flying onwards to Rome. The aircraft departed Paris at 19.30 hrs and arrived in Rome at 22.30 hrs. There were no reports of further injury to the passengers.

1.2 Injuries/Medical Attention

While there were no reported injuries to persons on board the aircraft, a number of passengers did experience some ear discomfort, as a result of the emergency descent. After normal disembarkation, the airport authority provided a reception room for all passengers who wished to avail of medical examination by the airport medical services.

A total of 20 passengers, one minor and three cabin crew members (CCM's) did accept the offer of medical examination. These examinations determined that 16 passengers suffered intense ear ache due to rapid descent/pressure change, while two other passengers suffered from slight nose bleeds.

1.3 Pressurisation System Description

1.3.1 General

Cabin pressurisation is controlled during all phases of airplane operation by the cabin pressure control system. The cabin pressure control system includes four control modes, which are available by selecting automatic mode (AUTO-mode), standby-mode (STANDBY-mode), manual-AC (MAN-AC) or manual-DC (MAN-DC) pilot-controlled modes. The system uses bleed air supplied by the engines and distributed to the air conditioning system. Pressurisation and ventilation is controlled by modulating the outflow valve. In the MAN-mode the valve can be operated independently either by an AC servo motor or by a DC servo motor. Under these circumstances the MANUAL annunciator light over the control panel comes on. Two safety over-pressure relief valves are also incorporated into the system. Cabin altitude is normally rate-controlled by the cabin pressure controller up to a cabin altitude of 8,000 ft at the aircraft maximum certified ceiling of 37,000 ft.

In AUTO-mode, the pressure rate of change is automatically controlled. The outflow valve is controlled through the AC servo motor and the pressurisation control panel is used to preset two altitudes into the auto controller:

- FLT ALT (flight or cruise altitude).
- LAND ALT (landing or destination airport altitude).

The STANDBY-mode is a semi-automatic backup to the AUTO system, but can also be independently selected by the crew. The outflow valve is now controlled through the DC servo motor. The pressure rate of change is manually controlled and the pressurisation control panel is used to preset two parameters into the auto controller:

- CABIN ALT
- CABIN RATE

The controller programs the cabin to land slightly pressurised, so that rapid changes in altitude during approach result in minimum cabin pressure changes. While taxying in, the controller drives the outflow valve slowly to the full open position depressurising the cabin. If certain limits are exceeded in AUTO-mode during flight, then the system automatically reverts to STANDBY-mode.

In the MAN-AC-mode, the outflow valve position switch is used to operate the AC servo motor on the outflow valve by monitoring the cabin altitude panel and valve position on the outflow valve position indicator.

In the MAN-DC-mode, the DC servo motor powered by the DC standby bus, drives the outflow valve at a slower rate than the automatic modes. Outflow valve full range of motion takes up to 20 seconds.

Pressurisation control is automatically transferred from automatic mode to standby mode if the cabin pressure rate of change exceeds 1.0 p.s.i. per minute or cabin altitude exceeds 13,895 feet. The AUTO FAIL and STANDBY lights will then come on. However, if the standby mode is for any reason inoperative, only the AUTO FAIL light will come on.

There is a Delta P (Pressure) module installed adjacent to the pressure controller, which provides a maximum of 7.45 p.s.i. with the pressurization mode selector in AUTO-mode and 28,000 ft or below selected on the FLT ALT selector. A 7.8 p.s.i. differential is provided when FLT ALT above 28,000 ft is selected, with the pressurization mode selector in AUTO-mode. STANDBY-mode maximum pressure differential is 7.8 p.s.i.

Under certain circumstances where either the AC power or the DC power is temporarily withdrawn from the system, the outflow valve shaft may be locked in position either by the AC actuator clutch or DC actuator clutch engagement. Under these circumstances the valve position indicator may indicate the outflow valve in the closed position. There are three separate AC power supplies and three DC power supplies to the pressurisation control system. The absence of any one of these may cause loss of control depending on the mode selected.

1.3.2 Cabin Pressurisation Outflow Valve

1.3.2.1 The outflow valve is a thrust recovery rotating gate valve which is driven by either a rotary DC electrical actuator or a rotary AC electrical actuator. Each actuator connects to the gate shaft with an electrically operated spring-loaded clutch. AUTO and MAN-AC modes operate the AC actuator. STANDBY and MAN-DC-modes operate the DC actuator. When either actuator is in operation the clutch to the other actuator is automatically disengaged.

1.3.2.2 With no electrical power to the clutches, the DC actuator clutch is spring loaded disengaged and the AC actuator clutch is spring loaded engaged. With electrical power to the clutches, the DC actuator clutch is engaged and the AC actuator clutch is disengaged. The clutches are energized when operating from the standby system or the manual DC system thus disconnecting the outflow gate shaft from the AC motor and at the same time connecting the shaft to the DC motor.

1.3.3 Pressure and Relief Valve

The Pressure and Relief Valve prevents a negative pressure differential from becoming great enough to damage the aircraft. The valve consists of a spring-loaded door which relieves automatically at a negative pressure differential. It is located in the aft cargo compartment under the floor at the right hand door.

1.3.4 Safety Relief Valves

Two safety relief valves acting independently of each other and all other systems, prevent the cabin-to-ambient positive pressure differential from exceeding 8.5 p.s.i.

1.4 Aircraft Maintenance

1.4.1 Previous "C" Check.

The aircraft completed a "C" Check on 13/11/00. Following its "C" check, the single pack dispatchability confidence check was carried out. This checks the ability of the air conditioning pack(s) to provide sufficient inflow of air and the ability of the aircraft structure to maintain cabin pressure.

1.5 Technical Examination on Aircraft Return.

The aircraft was ferried back to EIDW and the following items replaced:

- Cabin Pressure Controller (CPC).
- Pressure Selector Panel.
- Aft outflow valve and heated gasket.
- Right hand safety relief valve.

- Left hand safety relief valve
- CVR and FDR.
- 39 Passenger PCU's (due to oxygen generators used)

The aircraft was pressurised to 4 p.s.i., with both air supply packs in AUTO-mode. The pressure held on one pack and with both packs in AUTO, the pressure decay rate was 2,100 ft/min. The maximum pressure decay is not to exceed 2,250 ft/min. As a result of aircraft sealing and supply pack problems, two test flights were required. It was estimated, however, that this small loss in pressure could not account for the rapid depressurisation during the incident flight.

Shop testing was carried out on all the above units, with the exception of the CPC's, which were returned to the manufacturer for testing. In-house tests of the remaining units showed no significant faults on any of the units tested. However, the outflow valve was later sent to the same manufacturer for testing in conjunction with the CPC.

Later it was found that a Hi-Stage Bleed valve of No. 2 pack had a sticking butterfly valve and therefore the supply pack was replaced.

The following component faults were found:

(a) CPC - Autofail transfer fault found.

(b) Outflow Valve - AC actuator failure when unit was preheated. (Feedback potentiometer found outside limits)

1.6 Flight data Recorder (FDR) Information

The aircraft took off at 12.59 hrs and had an initial rate of climb of 2,413 ft/min to FL 280, followed by a climb to FL 330 at a rate of 1,046 ft/min. After 11 minutes at that altitude, the aircraft finally climbed to FL 370 at a rate of 930 ft/min.

At 13.31 hrs, the aircraft reached FL 370 and levelled off. After five minutes at this level, at a heading of 140° M, the aircraft made a 20° roll to a new heading of 152°M. During this time there were only small changes in lateral and normal accelerations. Short transmissions on VHF accompanied this change in heading. There were no further changes in flight parameters for a further six minutes until a number of transmissions were made commencing at 13.42 hrs.

At 13.43 hrs, the MASTER CAUTION came on and 16 seconds later went off again. There then followed transmissions for a further two minutes until at 13.45 hrs the aircraft commenced it's descent. It descended at a rate of 4,500 ft/min, taking six minutes to reach FL 100.

1.7 Additional Information

1.7.1 Threshold Altitudes and Physiological Limitations

The varying nature and effects of altitude/hypoxia on the individual are covered in AAIU Report No.2001-014, which reported on the absence of pressurisation in flight on a similar B737-500 two days previously to this particular incident.

In February 2001, the Operator's Flight Operations Department published an account of this incident in an "Incident Information" letter to all line pilots in an effort to inform flight crews on overcoming faults which may occur in the different components of the pressurisation system.

2. ANALYSIS

The pressurisation control is automatically transferred from AUTO-mode to STANDBY-mode, if the cabin pressure rate of change exceeds 1.0 p.s.i. per minute or the cabin altitude exceeds 13,895 feet. A rate of cabin altitude rise of 1,500 ft/min would be within these parameters. As the Captain switched control to STANDBY-mode, it would indicate that these values had not been exceeded. However, it subsequently transpired that there was an AUTOFAIL transfer fault found in the CPC. There was also a fault found in the AC actuator of the outflow valve.

The crew then found that the STANDBY-mode was not operative in controlling cabin pressure and that the rate of cabin altitude rise was increasing.

A differential pressure of 6.9 p.s.i. at FL 370 would indicate that the cabin altitude was approaching 10,000 ft prior to descent. The cabin altitude warning horn, which activates at 10,000 ft cabin altitude, sounded about two minutes before descent commenced.

The crew switched to MAN-AC-mode. However, the cabin continued to climb. It was not indicated whether MAN-DC-mode was used. The aircraft then descended to 10,000 ft at a rate of 4,500 ft/min.

The Captain had been informed that two loud bangs had been heard below the floor near the rear right hand door. The Operators report does not indicate if this occurred at FL 370 or during the subsequent descent. Under normal operation the outflow valve takes 20 seconds to go from a fully open position to a fully closed position and one would not expect that this would be heard in the cabin during flight. The controller provides voltage signals to the outflow valve which causes the valve to modulate the flow of cabin air in order to maintain pressure at the desired level. However, if the feedback loop were broken in any way the actuator motor could go "hard over" and this might be felt at the rear of the cabin.

The relief valves do not function during normal operation of the aircraft. However, if there was a sudden change in cabin-to-ambient negative pressure as probably was experienced during the rapid descent, the Safety and Relief valve could open suddenly producing a loud bang. The cabin crew heard the noise emanating from that location but the Operator's report does not indicate exactly when these bangs were heard.

As no fault was found with the DC actuator, the crew should have been able to control cabin pressure with the MAN-DC-mode. However, it should be stated that under certain electrical power anomalies, the valve position indicator in the cockpit could indicate closed when in fact the outflow valve is open.

No single fault could account for the rapid loss of pressurisation. It is concluded that a combination of factors, including failure of the CPC in AUTO-mode and a defective outflow valve, coupled with an intermittent supply pack fault could have given rise to this loss of pressurisation.

3 CONCLUSIONS

(a) Findings

3.1 Control over the pressurisation was lost whilst at FL 370.

3.2 The flight crew responded to the emergency in both an efficient and professional manner.

3.3 Faults were subsequently found by the manufacturer on the CPC and the outflow valve actuator.

3.4 Two test flights were later required in order to confirm the Operator's dispatchability confidence check on this aircraft.

(b) Causes

A combination of factors, including failure of the CPC in AUTO-mode and a defective outflow valve, coupled with an intermittent supply pack fault could have given rise to this loss of pressurisation.

4. SAFETY RECOMMENDATIONS

Safety Recommendations pertaining to this report and a similar type event are made in AAIU Synoptic Report No. 2003-013.