Boeing 737-204 ADV, G-SBEB

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Aircraft Type and Registration:	Boeing 737-204 ADV, G-SBEB
No & Type of Engines:	2 Pratt & Whitney JT8D-15 turbofan engines
Year of Manufacture:	1974
Date & Time (UTC):	13 August 1998 at 2120 hrs
Location:	Between Ostend and Dover
Type of Flight:	Public Transport
Persons on Board:	Crew - 6 - Passengers - 115
Injuries:	Crew - 1 Minor - Passengers - 4 Minor
Nature of Damage:	Cracked aft cargo door
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	18,950 hours (of which 8,100 were on type)
	Last 90 days - 60 hours
	Last 28 days - 44 hours
First Officer's Flying Experience:	1,554 hours (of which 111 were on type)
	Last 90 days - 108 hours
	Last 28 days - 63 hours
Information Source:	AAIB Field Investigation

History of the flight

The flight deck crew reported for duty at 1430 hrs, and the cabin crew 30 minutes earlier at 1400 hrs. The flight departed from London Gatwick Airport on schedule and arrived at Dubrovnik at 1807 hrs. None of the crew observed anything abnormal on the outbound flight. The return flight departed one hour later and was uneventful until the incident occurred.

The aircraft had been in the cruise at Flight Level (FL) 350 with the autopilot engaged. Ten minutes before the expected start of descent, the commander went back to the toilet which was located at the rear of the cabin. On his way back to the flight deck he invited a female passenger to go forward to view the flight deck. After they had returned to the flight deck the commander resumed his seat. Shortly afterwards, at 2100 hrs, ATC requested the aircraft to descend to FL280. The first officer carried out the descent checks and closed the thrust levers to initiate the descent. However he then felt pressure in his ears and therefore checked the cabin pressurisation panel above his head. He observed that the cabin rate of climb indicator was at the top of its scale and pointed this out to the commander. The first officer then attempted to control the rate of climb, by switching to the standby system, but it had no effect. He therefore decided to put on his oxygen mask, which he managed without difficulty.

When the commander realised that there was a problem with cabin pressurisation his initial concern was to advise the visiting passenger on the flight deck to return to her seat, which she then did. He checked the cabin altitude indicator and saw that it was reading 20,000 feet. He therefore attempted to don his oxygen mask, but in doing so it became entangled with his spectacles and knocked them to the floor. He tried to retrieve them but lost consciousness and slumped forward. The first officer saw the commander slump forward and reached over to try to assist him, but was unable to do so.

The first officer then returned his attention to the aircraft, which was still at FL350, and noticed that the indicated airspeed had decreased. He initiated a descent to regain airspeed and transmitted a MAYDAY call to Maastricht ATC, requesting an immediate descent. However this transmission was partially blocked and there was initially no response from the controller. The first officer therefore repeated his emergency call and was then cleared to descend to FL250. Since this level was insufficient for a depressurisation emergency descent, the first officer repeated his MAYDAY call with increased urgency and twice more requested "immediate descent". The controller repeated the clearance to FL250 and advised that if the aircraft were to turn right, they could descend to any level. The first officer then transmitted another call in which he included the information that several people were unconscious. He was again cleared for descent to any level and was then given a radar heading.

In the forward galley the senior cabin crew member had felt pressure in her ears, heard a 'bang' and felt a rush of air, with 'misting' around. She immediately deployed the crew oxygen by manually opening the panel in the ceiling. In the cabin the passenger oxygen masks had automatically deployed and were used by all of the passengers. The passenger who had returned from the flight deck was able to take a seat in the front row of the cabin and to put on an oxygen mask.

The first officer then used the cabin call chime to attract the attention of the senior cabin crew member, who then went to the flight deck. However in order to enter the flight deck she had to remove her oxygen mask and although she knew that a portable oxygen set was stowed above row 8, she decided against the delay in retrieving the set and went straight onto the flight deck. The first officer pointed to the commander and indicated that she should try to assist him. However before she was able to do so she collapsed onto the floor next to the flight deck door. The first officer therefore made another attempt to put the commander's oxygen mask on for him, and fortunately succeeded.

Once the commander was on oxygen he regained consciousness. His first action was to deploy the speedbrake to increase the rate of descent. He then attempted to communicate with the first officer through the flight interphone, but was in fact transmitting to ATC. However he could not hear ATC at this time because of background noise as a result of his inadvertent selection of ADF identification on his audio selector. The commander was unaware that he had been unconscious and remained so until after the ensuing landing.

The first officer looked back through the open flight deck doorway and indicated to another cabin crew member to assist her colleague lying on the flight deck floor. She brought a portable oxygen set forward and administered oxygen to the unconscious senior cabin crew member, who subsequently recovered sufficiently to return to her crew seat.

The controller passed a new frequency for the aircraft to contact the London ATC Centre (LATCC). When the first officer then contacted LATCC, he was asked by the controller if he was declaring an emergency. The first officer affirmed the emergency and requested radar vectors for an Instrument Landing System (ILS) approach into Gatwick Airport. The commander resolved his own communication problems after some minutes and was able to take over ATC communications from the first officer as the aircraft passed through FL110.

The aircraft proceeded to Gatwick Airport where it made an uneventful approach and landing. It was parked on a pier stand and the passengers then disembarked normally into the terminal, where they were offered assistance. Four passengers, and the aircraft commander, were then taken to a local hospital for treatment.

Flight recorders

The Flight Data Recorder was read out by an airline sub-contractor and the information supplied to the AAIB. The following nine basic parameters were recorded: altitude, airspeed, magnetic heading, pitch and roll attitude, engine power, normal acceleration and the RT transmission keying. There was no recording of cabin pressure and therefore no indication of exactly when the depressurisation had occurred. The data showed that whilst in the cruise at FL350 power was reduced on both engines initially and the airspeed began to decrease, reducing to a minimum of 180 kt after 2 minutes. The pitch attitude then reduced from 10° maximum and the aircraft began to descend at a rate of 4,000 feet per minute initially. The airspeed then increased to a maximum of 373 kt at an altitude of 18,000 feet, by which time the rate of descent had increased to 7,000 feet per minute. The time taken to descend to 14,000 feet was 4 minutes and 15 seconds; the aircraft continued to descend to 8,000 feet for a further period of 2 minutes. During the descent the aircraft turned left from a heading of 300° onto 250°.

Engineering investigation

Initial engineering investigations were made by the line maintenance organisation contracted to the operator. They attempted to pressurise the aircraft on the ground but, at a cabin pressure of only about 2 psi, the lower aft corner of the aft cargo door was seen to gape open by about half an inch, and it was not readily possible to pressurise the aircraft further. Initial examination of the door, which opens inwards into the baggage bay, found a crack in the aft cargo door frame member at the aft/lower corner. The crack extended along the radius between the outer skin attachment flange and sidewall elements of the door frame section, from just above the lower aft stop fitting to a point at the start of the straight portion of the door lower edge (see Figures 1 and 1a). The crack was only visible when the door was opened, the insulation removed from the inner face of the door, and the skin strained by pushing it outwards from the inside. There were also some cracks in the lower stop beam outer chord and web members, close to the corner where the frame crack had occurred (see Figures 2 and 3).

The door was removed and taken to the base maintenance engineering company, which was contracted to the operator, for further examination under AAIB supervision. After removal of the door inner skin, the cracked lower aft frame section was removed and lengths of the cracked elements at the aft end of the lower stop beam were cut out. These were then taken for detailed metallurgical examination.

Metallurgical examination revealed that the crack in the frame had initiated in fatigue at multiple sites, over a length of about 1 inch, in the inner radius of the outer flange-to-sidewall bend of the frame section. These initiating sites had occurred at the position of the lower aft stop fitting attachment and before the cracks had extended to the outer surface, the propagation mechanism had changed from fatigue to fast tearing, extending to a total length of some 12 inches over a very short period of time. The crack had remained in the radius of the flange-to-sidewall bend and extended mainly downwards and around the lower aft corner of the door.

The crack in the web of the beam (Figures 2 and 3) had propagated entirely by a high cycle tensile fatigue mechanism. The origins of this crack were at the first rivet hole forward of the aft stop fitting that attached the beam web to the outer chord. The multiple branched crack in the lower chord member flange (Figures 2 and 3) had fatigue origins at all three of the holes for the fasteners which attached the stop fitting to the lower beam web and outer chord. The three cracks had coalesced and had then run to two free edges of the outer chord flange, thereby making the outer chord ineffective for the transference of stop loads into the lower beam. Examinations revealed that the crack surfaces at the origins in all three fastener holes in the chord were contaminated with a polysulphide anti-fretting compound, of a type dissimilar to that used by the manufacturer.

At the time of this incident, the aircraft had flown a total of 35,385 flight cycles with a flight time of 86,446 hours. Over this period the cargo door had been the subject of two related Service Bulletins (SBs). The first, SB 737-52-1065 which was related to FAA Airworthiness Directive 76-26-02, called for the inspection of the corner stop fittings, attached to the upper and lower beams of both forward and aft cargo doors, and their replacement with new specification fittings. SB 737-52-1065 was embodied in two stages on this aircraft, with the lower fittings on this aft cargo door having been replaced in September 1981, at which time the aircraft had flown some 12,000 flight cycles over 25,000 hours.

The stop fittings are attached to both the frame and beam members of the door structure, and the fasteners which attach the stop fitting to the beam also attach the inner and outer chords to the beam web (see Figure 3). The polysulphide compound found present inside the cracks in the outer chord member was of a type which cures shortly after application. This indicated, therefore, that the cracks had already initiated and propagated an appreciable distance by the time that wet polysulphide had been applied to the joint of the stop fitting to the beam when the stop fitting had been replaced in accordance with Service Bulletin 737-52-1065.

This indicated that, at the time that the stop fitting modification had been embodied, these cracks in the beam had not been noticed by inspection. It was noted that SB 737-52-1065 did not specify that there should be an inspection of the structure to which the stop fitting is attached.

Notwithstanding this oversight at the time when the stop fitting was replaced, subsequent inspections in accordance with the second related SB, 737-52-1079, should have discovered both these and the crack in the lower beam web. Although the instructions within this SB had a tendency to emphasise inspection for cracks in the frame members of aft cargo doors, it was entitled 'Frame and Beam Inspection, Modification and Repair', and the beams are specifically mentioned several times as being required to be inspected. This SB called for the inspection of the frames of the cargo doors and the ends of the upper and lower beams, and recommended the fitting of reinforcement angles to the door frame corners before 75,000 flight cycles had been accumulated.

Although this SB was not the subject of an FAA Airworthiness Directive, the CAA had made it an Additional Airworthiness Directive (AAD Boeing 737 001-06-89). This inspection had last been performed during a 'C' Check on 11 November 97, at which time the aircraft had flown 34,460 flight cycles over 84,772 hours; the record sheet for this inspection stated 'no defects found'.

During the investigation it was noted that although the crack in the door frame was extensive it was difficult to see, particularly with the (inward opening) door still fitted to the aircraft, since its location was obscured by the seal and seal carrier, and it was in the edge radius where the frame attached to the outer skin. However the frame crack, and the cracks in the beam, were readily observed through the lightening holes in the door inner skin when the inner lining of the door had been removed.

It was thus evident that the cracks in the door beam members had existed for some 17 years without having been detected, despite the fact that this area of the door had been modified in accordance with FAA AD 76-26-02 in September 1981, and that the door had later been subject to the particularly relevant inspection requirements of CAA AAD Boeing 737 001-06-89 in November 1997.

Rapid depressurisation procedures

When the automatic pressure control in the cabin fails the system will automatically default to the standby mode. If pressure is still not controlled, manual control of the outflow valve has to be used.

The Quick Reference Handbook (QRH) procedures for rapid depressurisation give the following sequence of actions: Oxygen masks and regulators - ON; crew communications - ESTABLISH; pressurisation mode selector - MANUAL; outflow valve switch - CLOSE; 'no smoking-fasten seatbelts' - ON; passenger oxygen - ON; and if required, emergency descent - INITIATE. The emergency descent actions include closing the thrust levers, deploying the speedbrake and levelling off at 14,000 feet.

Safety equipment

The passenger oxygen supply is a continuous flow system using a pressurised cylinder with passenger masks automatically released when the cabin altitude reaches 14,000 feet. The masks are individually activated when pulled down to the face. The oxygen supply is diluted by cabin air with each breath and the masks have a transparent plastic bag in the supply line to conserve any unused oxygen. This caused concern amongst some passengers who thought that when the bag was empty the oxygen supply had failed.

There are four crew oxygen stations on the flight deck, one outboard of each pilot, and one outboard of each observer's seat. Each station has a supply ON/OFF switch and pilots are required to check their own masks and regulators before flight. There is no requirement for the other two masks to be tested or switched ON for flight, unless an associated observer's seat is occupied.

The aircraft was equipped with four portable oxygen sets, two located above row 8 and two at the rear of the cabin.

Hypoxia

When the cabin altitude is suddenly increased, a person will experience the effects of a lack of oxygen after a short time. In cruise flight at FL350 the cabin altitude is normally maintained at 8,000 feet. The company Safety and Emergency Procedures (SEP) Manual quoted a 'time of useful consciousness' figure for different altitudes. For a change from 8,000 feet to 25,000 feet, 3 to 4 minutes was quoted and for a change from 8,000 to 30,000 feet, 1 minute was quoted.

'Time of useful consciousness' is a relative term and will vary for individuals, the most significant effect upon the time being the level of activity. A time of one minute does not imply that a person will be fully capable for all of that time. Characteristically, initially a person will be able to carry out multiple tasks but then performance will decline and the individual will tend to focus on one task, not necessarily the most important. Once recovered it is not unusual for a person to be unaware of having had a period of reduced consciousness.

Rapid decompression procedures are regularly reviewed for pilots in simulator refresher training. There are also SEP annual refresher courses in training for both pilots and cabin crew. Crews will not usually have actual experience of decompression, but in this case both the commander and the first officer had received training in a hypobaric chamber during their previous military careers.

Discussion

ATC procedures

This incident occurred in an area of airspace where four different control sectors have to co-ordinate a clear area for an emergency descent. Mayday calls were clearly broadcast by the first officer but some of the initial transmission was blocked which may have been why the controller did not acknowledge the Mayday. Only after the first officer had transmitted a third Mayday call, in which he informed the controller that several people were unconscious, did the controller clear the aircraft to descend to any level, with an associated radar heading. There was thus some delay in the first officer receiving the rapid descent clearance and radar heading information which he felt he required, particularly in view of the commander's incapacitation, but this appeared partly due to the blocked transmission which is always a potential problem during RT communication in busy airspace sectors, and to the presence of other traffic at lower levels.

Cabin altitude

There was no record on the FDR of the actual cabin altitude attained during the incident, but there were several indications of a very rapid decompression. The passenger's oxygen masks were reported to have deployed very shortly after the change in pressure was felt, and these deploy at 14,000 feet. The fact that two crew members were rendered unconscious suggested that the cabin must have reached a significantly high altitude, probably in excess of 20,000 feet, and at a rapid rate.

Since these two experienced crew members rapidly succumbed to the effects of the depressurisation, it is also possible that neither fully appreciated the nature of hypoxia. The term 'time of useful consciousness' may lead crew members to assume that a longer time is available for performance of tasks than is actually the case. The timescale 'window of opportunity' for donning oxygen and securing personal safety, and thereby that of the aircraft, can be very limited and must take overriding precedence. In view of the commander's experience in this serious incident, and his previous RAF decompression training, it would appear that even those crew members who have had the benefit of decompression training in hypobaric chambers in the past may not be immune from failing to recognise the importance of immediate action to protect respiration.

Crack propagation rate

In response to the draft copy of this Bulletin, the aircraft manufacturer reviewed past events involving such cracking and commented that the associated results indicated that the final propagation of cracks in previous cases had tended to take several flight pressurisation cycles and typically resulted in an inability to pressurise the aircraft once cracks had grown sufficiently. However in this case there had been no reports of difficulty having been experienced in pressurising the aircraft during previous flights. This, and the fact that a rapid depressurisation had occurred late in this flight, supported the metallurgical assessment that the final propagation of the crack had been by a fast tearing mechanism.