Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200506298

Final

Warning device event – 46 km west of Mackay, Qld
2 December 2005
VH-VBC
Boeing 737-7Q8

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Abstract

On 2 December 2005, a Boeing Company B737-7Q8 aircraft, registered VH-VBC, was being operated on a scheduled passenger flight from Townsville to Brisbane Qld. While the aircraft was passing flight level 370 on climb, the crew heard a 'bang', which was closely followed by the annunciation of a Window Overheat master caution. After becoming aware that the outer layer of the pilot in command's L1 window was cracked, the crew followed the checklist for window damage. As a result, at about 2106 Eastern Standard Time, a cabin altitude warning horn sounded. The sounding of the warning horn was the normal result of the crew's implementation of the checklist for window damage. However, the flight crew believed that the aircraft was depressurising as a result of the window damage and responded to the cabin altitude warning by carrying out an emergency descent from 33,000 ft to 10,000 ft.

During the descent, the crew closed the valve that controlled the outflow of air from the aircraft. However, the pressurisation system was functioning normally and closing the outflow valve caused the aircraft to exceed its cabin pressure limit, as a result of which the over-pressure safety relief valves opened. The flight crew realised that the aircraft was not depressurising, but pressurising, and opened the outflow valve. The combined action of the crew and the automatic opening of the safety relief valves reduced the cabin pressure at a rate greater than that which passengers normally experience. As a result, 11 passengers sustained minor injuries.

Following a company investigation, the operator retrained the flight crew involved in the incident, audited its check and training system and modified the simulator programme to include operational issues identified in this incident.

The aircraft manufacturer has modified the checklist for window damage to minimise the possibility of a cabin altitude warning occurring when the checklist is used.

The operator, in conjunction with the manufacturer, is still investigating the cause of the window breakages.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations. Accordingly, the ATSB also conducts investigations and studies of the transport system to identify underlying factors and trends that have the potential to adversely affect safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and, where applicable, relevant international agreements. The object of a safety investigation is to determine the circumstances in order to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and findings. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety issues, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau prefers to report positive safety action in its final reports rather than making formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety issue may lead to a number of similar recommendations, each issued to a different agency.

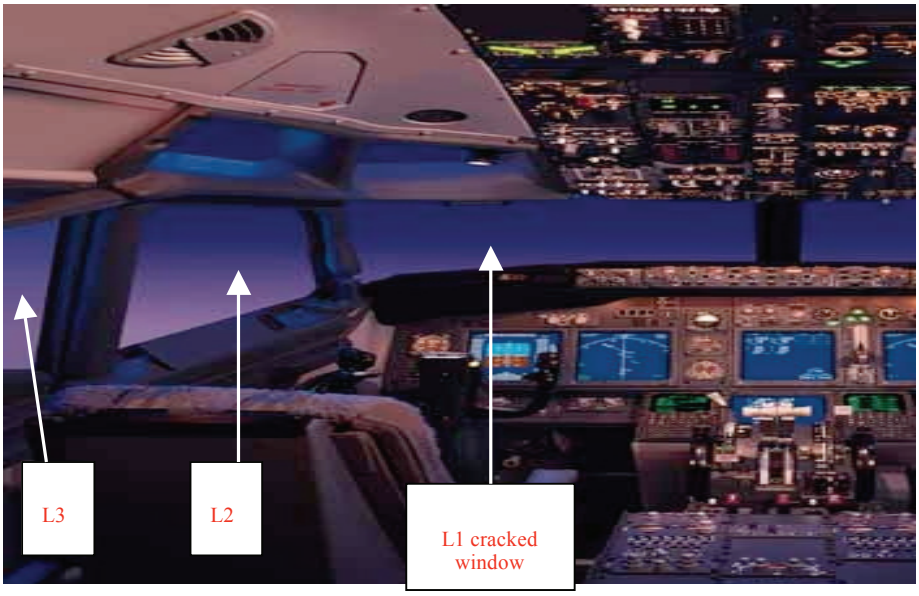
The ATSB does not have the resources to carry out a full cost-benefit analysis of each safety recommendation. The cost of a recommendation must be balanced against its benefits to safety, and transport safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example, the relevant regulatory authority in aviation, marine or rail in consultation with the industry).

FACTUAL INFORMATION

Sequence of events

On 2 December 2005, a Boeing Company B737-7Q8 aircraft, registered VH-VBC, was being operated on a scheduled passenger flight from Townsville to Brisbane Qld. At about 2057 Eastern Standard Time[1], while passing flight level (FL) 370 on climb to FL410[2], approximately 46 km west of Mackay, the crew heard a 'bang', which was closely followed by the annunciation of a Window Overheat master caution. The crew responded by carrying out the non-normal checklist (NNC) actions for a window overheat. During that time, the crew became aware that the outer layer[3] of the aircraft's forward windscreen on the pilot in command (PIC) side (L1) (figure 1) was cracked. The crew then followed the NNC for window damage, while descending the aircraft from FL403 to FL330. At that time the aircraft's cabin altitude was about 8,000 ft.

Figure 1: Window Layout



1 The 24 hour clock was used in this report to describe the local time of day, Eastern Standard Time (EST), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

2 FL410 was approximately 41,000 ft above mean sea level (AMSL).

3 The L1 window was comprised of 3 layers: an outer and inner layer made of glass and a middle layer made of vinyl.

The checklist actions for the L1 window damage required the crew to reset the landing altitude[4] on the cabin pressurisation panel to 10,000 ft, to reduce the difference between the aircraft's internal pressure and atmospheric pressure, commonly referred to as differential pressure. Reducing the differential pressure minimises the load on the aircraft structure and the potential for structural failure. A review of the cockpit voice recorder (CVR) showed that the crew incorrectly reversed the number order of the windows. They used the NNC checklist for the L3 window (figure 1) and set a landing altitude of 13,000 ft as required by that checklist.

The flight crew later reported that they understood that the pressurisation system would not immediately target the new landing altitude. The pressurisation system however, was designed to target a new landing altitude immediately if it was greater than the current cabin altitude. The change in the landing altitude setting initiated an increase in the cabin altitude from about 8,000 ft to 13,000 ft.

The aircraft's pressurisation system was designed to activate a cabin altitude warning horn when the cabin altitude reached or exceeded 10,000 ft. At 2106, as the cabin altitude reached 10,000 ft, the cabin altitude warning horn sounded. The flight crew reported that that they believed that the aircraft was depressurising as a result of the window damage. On that basis they initiated an emergency descent from FL330 to 10,000 ft.

11 passengers sustained minor ear and/or nose injuries as a result of rapid changes in cabin pressure which occurred about 5 minutes after the emergency descent was completed.

Injuries to persons

The 11 injured passengers received attention from paramedics on their arrival in Brisbane and were transferred to hospital for further observation. They were all discharged from hospital later that day.

Table 1: Injury summary

Injury	Crew	Passengers	Total
Fatal	0	0	0
Serious	0	0	0
Minor	0	11	11
None	6	88	94
Total	6	99	105

4 The B737's pressurisation system maintained a nominal pressure differential in the aircraft cabin depending upon the altitude of the aircraft. As such the cabin altitude varied depending on the altitude of the aircraft and the nominal pressure differential (cabin altitude during flight at FL330 would be approximately 6,400 ft). The Landing Altitude was usually set to the elevation of the landing airfield so that when an aircraft landed there was a small pressure differential.

Window damage

An examination of the damaged window by the operator confirmed that the outer layer of the left side L1 window was shattered (figure 2).

Figure 2: L1 window damage

The L1 window was composed of three main laminated layers:

- one non-structural glass outer pane including a conductive coating (for anti-ice)
- one structural vinyl interlayer
- one structural glass inner pane without conductive coating.

The window was designed such that a failure of one layer of glass would not result in a loss of cabin pressure. The vinyl interlayer alone is used to carry pressurization loads if the structural glass inner pane fractures and is also used for bird impact resistance. For window anti-ice, voltage is applied by the Window Heat Control Unit (WHCU) through the conductive coating on the non-structural glass outer pane. Temperature sensors embedded in the window are continually monitored by the WHCU and voltage is applied as needed to maintain an internal temperature of approximately 43.3 deg C. A window overheat amber caution light would illuminate following the detection of a window overheat condition or if electrical power to the windows was interrupted.

The operator reported that there were 87 window damage events fleet wide in the 2005 calendar year. A review of these occurrences did not reveal any relationship between the window damage and: aircraft time in service; aircraft pressurisation cycles; year of aircraft manufacture; or window batch numbers.

At the time of this report, the underlying reason for the window damage events was still being investigated by both the aircraft manufacturer and the operator.

Personnel information

Records from the operator indicated that the crew were properly licensed, medically fit, adequately rested and qualified for the flight in accordance with existing

regulations. The PIC had completed a proficiency check in the aircraft simulator 2 days prior to the incident. During the check the PIC conducted an emergency descent as a result of an air-conditioning malfunction.

Table 2: Crew experience

	Pilot in Command	Copilot
Type of Licence	ATPL	ATPL
Medical Certificate	Class 1	Class 1
Flying Experience Total	12,908	4,000
Experience on Type	3,475	2,000
Hours in the preceding 30 days	58.4	67.5
Hours off prior to commencing work period	19.75	21.0
Last proficiency check	30 November 2005	26 July 2005
Age	43	30

Aircraft information

Pressurisation System

The purpose of the aircraft pressurisation system was to maintain sufficient cabin pressure for passengers to remain comfortable while the aircraft operated at high altitudes. Pressurisation allowed the sometimes large and rapid changes in aircraft altitude to be experienced as smooth, progressive and comparatively small changes in the cabin altitude.

The aircraft was pressurised by controlling the ratio of the air flowing into the cabin over the amount of air being exhausted. In the event that the outflow exceeded the inflow, the aircraft would depressurise. Where the inflow exceeded the outflow the aircraft would pressurise. At a constant atmospheric pressure, an increase in cabin pressure is shown on the cockpit pressure gauges as a decrease in cabin altitude and an increase in differential pressure. A decrease in cabin pressure is shown on the cockpit pressure gauges as an increase in cabin altitude and a decrease in differential pressure. To prevent an over-pressure condition, the aircraft was equipped with two positive pressure safety relief valves which would open when the differential pressure reached between 8.75 and 9.1 psi.

Cabin pressurisation control panel

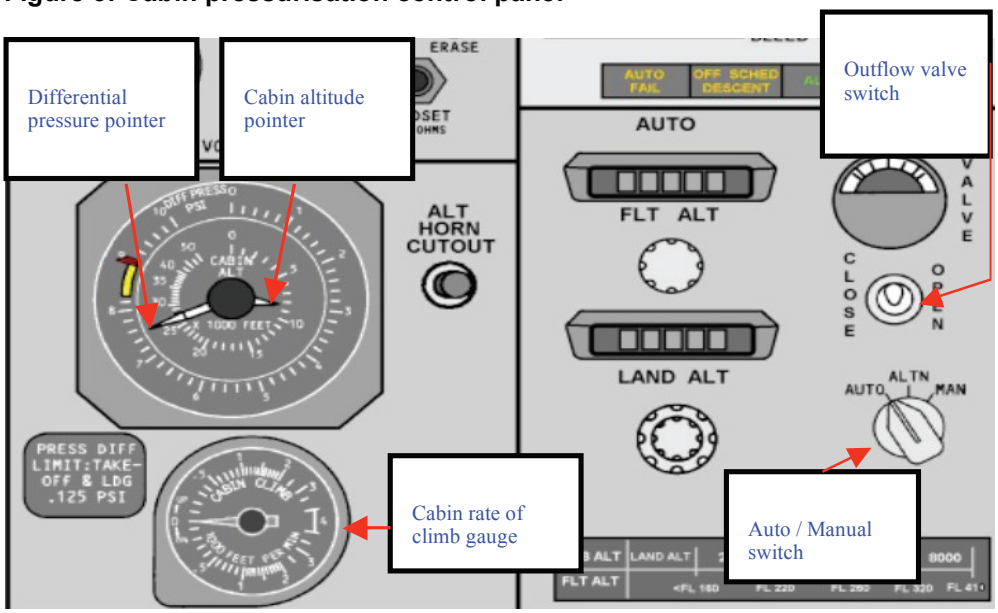
Cabin pressure was set and controlled using the cabin pressurisation control panel (figure 3). The flight crew could set a flight altitude (FLT ALT) of between negative (-) 1,000 ft and positive (+) 42,000 ft. The flight crew could set a landing altitude (LAND ALT) of between -1,000 ft and +14,000 ft. The system was usually operated in the automatic mode, where it would regulate the airflow ratio to achieve the flight altitude and landing altitude targets. The system could be switched from the automatic mode to a manual mode using a three position rotary switch. In the

manual mode, the FLT ALT and LAND ALT settings have no effect. To control the pressurisation of the aircraft in a manual mode, the flight crew would use a toggle switch to open or close the outflow valve to regulate the outflow of air. Operation in the manual mode would require a flight crew to closely monitor the cabin altitude, cabin rate of climb and cabin differential pressure.

Indicators of pressure

The gauge that indicated aircraft cabin altitude and differential pressure was a dual reading gauge (figure 3). The small pointer showed cabin altitude on the inner scale and the larger pointer showed differential pressure on the outer scale. The inner scale was not marked or calibrated to show negative cabin altitude values, although they could be set by the crew. As cabin altitude decreases, the cabin altitude pointer will move anticlockwise, past the zero position, into an unmarked section of the gauge. Further anti-clockwise movement will result in the pointer moving into the section of the gauge where high positive cabin altitude values are marked. The manufacturer reported that misreading of the cabin altitude gauge by flight crew was not common. The manufacturer stated that the pressure state of the aircraft should be determined by referring to the three indicators of pressure available: cabin altitude, differential pressure and cabin rate of climb.

Figure 3: Cabin pressurisation control panel



Meteorological information

Weather information between Townsville and Brisbane was provided by the Bureau of Meteorology. Moderate icing and turbulence was forecast in large cumulus and cumulonimbus clouds. The crew had planned to cruise between Townsville and Brisbane at FL390, but once airborne they elected to climb to FL410 to avoid the remnants of previously active storms in the area. On descent to FL330, following the shattering of the window, the aircraft entered cloud and encountered light turbulence.

On board recordings

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR). The FDR contained data from the most recent 25 hours of aircraft operation and included a cabin altitude (> 10,000 ft) warning discrete parameter. The CVR had a recording duration of 2 hours and the recording commenced during initial climb after takeoff at Townsville. Audio data relating to the initial window cracking event was recorded.

Crew actions

All aircraft in the operator's fleet were identified by a 3-digit airplane number, which was correlated to the registry number, serial number and tabulation number (table 3). The airplane number was displayed on a placard in the cockpit.

Table 3: Aircraft data

Airplane Number	Registry Number	Serial Number	Tabulation Number
703	VH-VBC	30638	YA338

The operator maintained a quick reference handbook (QRH), which was not aircraft specific. When using NNCs from the QRH the crew were required to action items that were applicable only to the aircraft they were operating. This was done by cross-referencing the checklist item to the airplane number (table 3 and Appendix A).

The action required of the crew in the event of window damage was set out in the NNC Window Damage, contained in the QRH. After it was determined that the window had been shattered, the PIC read this checklist, but the crew mis-identified the damaged window. A window layout diagram was not included in the window damage checklist or elsewhere in the QRH. The manufacturer considered that it was more appropriate to include a window layout diagram in the systems manual. The NNC did not require the crew to descend the aircraft as a result of the shattering of an outer layer of glass on any window.

The aircraft manufacturer prescribed (see Appendix C) that an emergency descent should be conducted when:

- the crew were unable to control cabin pressure with the aircraft above F140 or
- conditions required a rapid descent.

On receipt of the cabin altitude warning, the crew did not attempt to control the cabin pressure prior to initiating an emergency descent. The crew reported that they believed that the loss of cabin pressure was associated with the window damage and that further loss of pressure could not be prevented. Some time after commencing the emergency descent, the PIC instructed the copilot to action the Cabin Altitude Warning or Rapid Depressurisation NNC by recall[5]. In doing so, the pressurisation control switch was set to manual and the outflow valve was closed. After the crew

5 The intention is to carry out the NNC first from memory and then at a suitable time refer to the written checklist to ensure all checklist items were actioned correctly.

completed the recall items, the PIC requested that the PNF read the Cabin Altitude Warning or Rapid Depressurisation NNC from the QRH. This checklist required the crew to assess whether pressurisation had been restored and whether cabin altitude was controllable following their actions by recall (see Appendix B for the Cabin Altitude Warning or Rapid Depressurisation NNC). The checklist was started, but not completed.

The systems that supplied and controlled the inflow of air to the aircraft were operating normally. The investigation estimated that by closing the outflow valve, cabin pressure increased and resulted in the cabin altitude decreasing to the equivalent of about -7,000 ft. This was shown on the cabin altitude gauge as a positive altitude of about 35,000 ft. As the cabin pressure increased, so the differential pressure increased until the aircraft's positive pressure safety relief valves opened. Shortly thereafter, the crew reported that they opened the outflow valve. These combined events returned the aircraft's differential pressure to zero at a rate well in excess of that to which passengers and crew were normally subjected.

The crew completed the emergency descent at 2113. Flight plan data indicated that the equi-time point[6] would have been reached at about 2118. There were no meteorological factors, ATS issues or aerodrome usability issues which would have prevented the crew from diverting to Townsville. The flight crew reported they did not divert to Townsville because the company representative may not have been available. A company representative would have been necessary to arrange or provide essential passenger services.

The operator required its crew to respond to non-normal situations and use checklists in accordance with the guidelines published by the aircraft manufacturer. During a non-normal event, the pilot not flying[7] (PNF) was required to state the title of the checklist being used. The checklist was to be read aloud and items actioned in a clear, concise and systematic way, allowing sufficient time for acknowledgement and execution (where required) from the pilot flying (PF). Upon completion of all the checklist items, the PNF was required to state that the checklist was complete.

A review of the CVR indicated that there were several interruptions of an operational nature while the Window Damage NNC was being read. As a result, the checklist was read intermittently over a 4-minute period. A statement that the checklist was complete was not made. Qualifying statements in the Window Damage NNC and the Cabin Altitude Warning or Rapid Depressurization NNC were either read, but not discussed by the flight crew, or not read at all.

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6 An equi-time point is also referred to as a critical point. It is the position from which it would take an equal amount of time to proceed to the planned destination (Brisbane) or return to the departure aerodrome (Townsville).

7 During the emergency descent the PIC acted as the PF and the copilot as the PNF (also referred to as pilot monitoring). The role of PF and PNF changed between the PIC and copilot at various phases of the flight from Townsville to Brisbane.

Communication

The operator's flight crew training manual (FCTM) stated that:

> Crew resource management is the application of team management concepts and the effective use of all available resources to operate a flight safely. In addition to the aircrew, it includes all other groups routinely working with the aircrew who are involved in decisions required to operate a flight. These groups include, but are not limited to, aircraft dispatchers, flight attendants, maintenance personnel, and air traffic controllers. Throughout this manual, techniques that help build good CRM habit patterns on the flight deck are discussed. For example, situational awareness and communications are stressed…

A review of the CVR indicated that:

- at 2100 and 2102 the crew took about 5 seconds to attempt to identify the damaged window. At 2129 the crew correctly identified the damaged window by referring to the aircraft operations manual
- on receipt of the cabin altitude warning, at about 2106, the PIC took control of the aircraft from the copilot without using standard phraseology
- on receipt of the cabin altitude warning the PIC commenced the emergency descent without clearly advising the copilot of the type of malfunction he was responding to or the action he was taking
- on several occasions the words and phrases used by the flight crew to describe the operation of aircraft systems and to provide crew support or advice did not comply with the operator's standard operating procedures
- the emergency descent was completed at about 2113.

The flight crew believed that the aircraft's structure had been compromised as a result of the window damage and transmitted a Mayday[8] broadcast to ATC while carrying out the emergency descent. This declaration of aircraft distress was cancelled upon reaching 10,000 ft, after the crew had conducted a thorough inspection of the cracked windscreen and assured themselves of the aircraft's structural integrity.

At about 2121, ATC inquired as to whether there were any injuries to the passengers. At this time the PIC was experiencing a very high workload and was not in receipt of clear advice of any passenger injuries. He answered that there were no injuries.

The cabin crew operations manual stated that, following an emergency descent the cabin crew should (upon receiving the PIC's advice that a safe level had been reached) carry out a check of the cabin and passengers and then advise the cabin supervisor (CS) on their status. The CS, in turn, should then brief the PIC on the

8 International call for assistance. A distress call indicating that the aircraft is in grave and imminent danger.

same. The manual did not specify a method by which the cabin crew and CS were to do this task. The operator provided a two-page passenger injury form for staff to record passenger and staff injuries. These forms were not used in flight by the cabin crew. The CS provided passenger injury details to the PIC by annotating the passenger manifest at about 2151.

At about 2155, ATC again enquired as to whether there were any passenger injuries. The crew had received information that several passengers had earache and nosebleed. However following a brief discussion with the copilot regarding the meaning of 'injury', and in the absence of any clear definition of 'injury' in documents provided by the operator to the flight crew, the PIC again informed ATC that there were no injuries.

In most situations, ATC are able to contact an aircraft operator on behalf of flight crew if the crew is unable to contact the operator's staff at an airport. Also, ATC are an alerting service for emergency situations, including medical emergencies, and are able to coordinate an appropriate response. The declaration of an emergency (either urgency or distress as appropriate) by flight crew to ATC can also assist a situation by affording an aircraft priority for arrival to enable the earliest provision of medical attention to persons on board.

At about 2207, a successful request to provide medical assistance to the passengers on their arrival in Brisbane was made by the flight crew to the operator on the company radio frequency. The operator arranged for medical assistance to be provided to the passengers on their arrival. The aircraft landed at about 2231 and arrived at the parking bay at about 2235.

Organisational information

Flight operations

In December 2005, the operator advised all company flight crew of the operational implications of the window damage events. This advice included:

1. clarification of aspects of the current window damage NNC
2. reversion to an older aircraft shut down procedure when on the ground
3. clarification of aspects of the cabin altitude warning and emergency descent NNC
4. a caution regarding assessment of window delamination
5. modification to the current simulator training programme to include a window damage scenario.

The company's engineering department had been liaising throughout the year with the manufacturer to identify the underlying reason for the window damage events. Issue 27 of the company's Engineering Safety Shorts produced by the operator's engineering safety department was issued to company flight crew in December 2005.

In May 2006 the manufacturer issued a revised NNC for Window damage. The operator customised this NNC to include a window layout diagram and a format more appropriate to the fleet configuration options selected by the operator.

Aircraft manufacturer

The aircraft manufacturer was aware of the reliability problems with the windows. The manufacturer had issued two Fleet Team Digest reports, relating to window problems, to operators of the aircraft type in August 2005 and January 2006. The manufacturer also revised the Window Damage NNC in May 2006. That revision required flight crew to set a LAND ALT of 9,000 ft for the majority of window damage events [9].

9 Except for the case on the B737-800/900 series aircraft where a non-heated number-3 window shatters or cracks on both the inner and outer layers.

ANALYSIS

Operations

Flight crew actions

The crew mis-identified the damaged window and as a result of implementing the Window damage non-normal checklist (NNC), a landing altitude of 13,000 ft was set instead of 10,000 ft. The damaged window was identified with haste. Had the flight crew taken more time to communicate with one another or refer to the appropriate systems information for guidance, it is likely that the damaged window would have been correctly identified.

The intent of the window damage NNC is to reduce the differential pressure. It is reasonable to expect that in setting a LAND ALT of 13,000 ft, the flight crew would have understood that this would result in a reduction of the pressure differential by changing the cabin altitude. In setting a landing altitude greater than 10,000 ft, the crew should have expected to receive a cabin altitude warning. However a cabin altitude warning may have been generated had either value been set in the LAND ALT window. The mis-identification of the damaged window therefore was probably not a factor in the occurrence.

The emergency descent was initiated primarily because the flight crew were not expecting to receive a cabin altitude warning as a result of implementing the Window Damage NNC. The cabin altitude warning was mis-interpreted by the flight crew as an indication of an uncontrollable depressurisation following window damage. This mis-interpretation could have been avoided had the flight crew:

- understood the intent of the Window Damage NNC and the consequence of setting a LAND ALT of 13,000 ft
- understood that the warning in the checklist to '…use crew and passenger oxygen if required' implied that a cabin altitude warning could be generated.

It is likely that the crew would not have commenced an emergency descent in response to the cabin altitude warning had the NNC clearly expressed, rather than implied, that by following the window damage NNC procedure a cabin altitude warning could be generated.

The pilot in command's (PIC's) recent simulator check, involving an emergency descent, may have predisposed him to respond as he did to the cabin altitude warning. In any event, the PIC's decision to initiate an emergency descent, on receipt of the cabin altitude warning, erred on the side of caution.

After the PIC initiated the emergency descent, he requested that the cabin altitude warning or rapid depressurisation NNC items be carried out by recall. In carrying out these NNC items by recall, the crew selected manual control of the pressurisation system and closed the outflow valve. This caused the aircraft to re-pressurise. Following the actions carried out by the crew, by recall, the PIC requested that the NNC be read from the Quick Reference Handbook (QRH). This checklist required the crew to assess whether pressurisation had been restored and

whether cabin altitude was controllable. In order to make this assessment, the crew should have monitored the cabin altitude gauge, the differential pressure gauge, and the cabin rate of climb gauge. It is likely that this was not done until shortly before the positive pressure safety valves opened, after the aircraft had levelled out at 10,000 ft. The opening of these valves caused a rapid change in cabin pressure which probably caused the injuries to the passengers.

It is likely that after completing the emergency descent, the high positive cabin altitude indication on the cabin altitude gauge temporarily confused the flight crew. Had the gauge indicated negative cabin altitude values, the crew may have realised that the aircraft was re-pressurising and opened the outflow valve to gradually reduce the differential pressure. That action would probably have prevented the opening of the positive pressure safety valves.

Had the crew used the NNCs in accordance with the aircraft manufacturer's checklist guidelines, it is probable that they would have correctly identified the pressure state of the aircraft. It is likely that the crew communication and checklist usage was affected by concern regarding the structural integrity of the window and an elevated workload while operating in turbulence and cloud.

The crew completed the emergency descent about 5 minutes prior to reaching the calculated equi-time point (ETP). From this point, there was sufficient time to return to Townsville and be assured of the provision of an air traffic control (ATC) service. However, diverting to Townsville immediately after completing the emergency descent and prior to reaching the ETP would probably not have given the passengers access to medical attention significantly earlier than was provided by continuing to Brisbane. The availability or otherwise of a company representative in Townsville was also a valid consideration for the flight crew in their decision to continue the flight to Brisbane. In any case, the flight crew did not receive comprehensive information regarding the status of the passenger injuries until they had passed the ETP and were closer to Brisbane than Townsville.

The crew did not successfully contact the operator to advise of the passenger injuries until 24 minutes prior to landing. The crew's decision not to advise ATC of passenger injuries did not err on the side of caution. In most cases, ATC can be contacted by radio earlier than radio contact can be established with an operator. As a consequence, ATC can usually provide an earlier notification to emergency services of a need to respond. In addition, in a high traffic environment, where ATC are provided with early advice of passenger injury it is more likely that they can manage any sequencing or tracking requests to facilitate the earliest arrival of the aircraft and the provision of medical attention for passengers.

Communication between the cabin crew and flight crew

The cabin supervisor (CS) gave the PIC a list of the names of passengers requiring medical attention 38 minutes after the completion of the emergency descent. While acknowledging that the cabin environment was not static, the flow of information from the cabin to the PIC regarding the status of the passengers was not comprehensive or timely. This may be attributed to the absence of a procedure by which the cabin crew were to gather such information and pass it on to the CS, and ultimately the PIC. The two-page passenger injury forms were not used in flight to record and pass on the injured passengers' details to the PIC. The use of such forms was probably impractical in a cabin environment with multiple passenger injuries.

The use of these forms would probably not have ensured the more timely provision of information to the PIC regarding the status of the passengers.

Quick Reference Handbook

Non-normal checklists which are not aircraft specific require the checklist user to make an assessment of the applicability of a checklist item to the aircraft number, possibly at a time of stress and high workload. Determining the applicability of checklist data can reduce the time available for troubleshooting.

Manufacturer

Non-normal checklist

A cabin altitude warning will be generated when the cabin altitude equals or exceeds 10,000 ±1,000 ft. With the exception of shattering or cracking to both of the unheated inner and outer panes of window 3 on the B737-800/900 series aircraft, it is unlikely that a cabin altitude warning would be generated as a result of actioning the revised Window Damage NNC.

Cabin altitude gauge

The cabin altitude gauge does not indicate correctly across the entire altitude range selectable or achievable by the crew. The indication of a positive cabin altitude of about 35,000 ft, when in fact the cabin altitude was about -7,000 ft, was confusing and probably delayed the crew's troubleshooting.

FINDINGS

Contributory safety factors

Flight crew

The flight crew did not action several checklists in accordance with the operator's procedures.

The flight crew did not adequately monitor the pressurisation system after selecting manual pressurisation control and closing the outflow valve.

Manufacturer

The manufacturer's Window Damage non-normal checklist did not state that a cabin altitude warning could be generated by following the checklist procedure.

Other key findings

The operator did not have procedures and methods for the cabin crew to readily assess and record passenger injuries and communicate the same to the pilot in command.

The operator did not provide a definition of 'injury' for the guidance of the flight crew.

The cabin altitude gauge was not marked to show negative cabin altitude values.

SAFETY ACTION

Operator

As a result of the occurrence the operator:

- modified the Window Damage non-normal checklist (NNC)to minimize the likelihood of a cabin altitude warning being generated
- provided additional training to the flight crew involved in this incident
- modified the Recurrent [simulator] Training Program (RTP 4) to include a window damage event followed by a loss of cabin pressure, with a focus on flight management, checklist use and communication with ATC and other crew members
- conducted an audit of the company's check and training personnel to ensure consistency of instruction
- refined the system by which they assess the flight crew's aircraft systems and performance knowledge
- initiated a review of its aircraft and engineering safety data collection system in order to identify operational and engineering risks as early as possible
- published an *Inflight Communication Form* to enable the cabin supervisor to readily provide the pilot in command with passenger injury details in a summary form, and included procedures for the use of the form in the cabin crew operations manual.
- undertook to provide the flight crew with training targeted to correct knowledge deficiencies
- will place greater emphasis on flight crew training rather than evaluation on day 1 of the RTP
- in conjunction with the manufacturer, is still investigating the cause of the window breakages.

Aircraft Manufacturer

The aircraft manufacturer reviewed all Window Damage NNCs. Revised NNCs were released to all B737 operators in a Flight Crew Operations Manual (FCOM) Bulletin in May 2006. That revision included a change to the Window Damage NNC to set a LAND ALT of 9,000 ft (refer Appendix D).

The manufacturer investigated the feasibility of modifying the cabin altitude gauge by fitting a stop peg to prevent counter clockwise movement of the pointer beyond the -1,000 ft position (the minimum selectable). The gauge supplier however advised that restriction of the pointer movement by fitting a stop peg could cause

damage to the gauge's diaphragm mechanism or the pointer itself, such that the gauge accuracy could be affected.

The manufacturer also stated that:

> … given the lack of prior reports on in-service problems relating to misinterpreting the cabin altitude gauge and the fact that modifying the gauge would require a major redesign we believe that change to the gauge is not warranted at this time.

APPENDIX A - WINDOW DAMAGE NNC

WINDOW DAMAGE

Condition: **Arcing, delamination, shattered or cracked condition of any flight deck window is observed.**

WINDOW HEAT SWITCH (affected window) . . . . . OFF

- **Limit maximum airspeed to 250 knots below 10,000 feet**
- **Use crew and passenger oxygen, if required**

701 - 720, 801 - 821, 823 - 829

Checklist / airplane number applicability

If window 1, 2, 4 or 5 is affected:

LAND ALT . . . . . 10,000 FT

Reduce pressure differential by limiting flight altitude as indicated in the following tables.

Note: For MEA between 15,000 and 20,000 feet select a higher LAND ALT to maintain 2 psi differential. Above 20,000 feet, select MAN and maintain 2 psi differential.

Window 1, 2 or 5:

CRACKED PANE	MAX DIFF PRESSURE	APPROX FLT ALT
Outer	— No Restriction —	
Inner	5 PSI	26,000 FT
Both	2 PSI	15,000 FT

Window 4: A failed middle pane usually appears shattered and transparency is virtually lost.

CRACKED PANE	MAX DIFF PRESSURE	APPROX FLT ALT
Outer	— No Restriction —	
Middle	5 PSI	26,000 FT
Both	2 PSI	15,000 FT

701 - 720, 801 - 821, 823 - 829

If Window 3 is affected:

LAND ALT . . . . . 13,000 FT

Reduce pressure differential by limiting flight altitude as indicated in the following table.

Window 3:

CRACKED PANE	MAX DIFF PRESSURE	APPROX FLT ALT
Outer	— No Restriction —	
Inner	— No Restriction —	
Both	0 PSI	13,000 FT

721, 722, 822

LAND ALT . . . . . 10,000 FT

721, 722, 822

Reduce pressure differential by limiting flight altitude as indicated in the following tables.

Note: For MEA between 15,000 and 20,000 feet select a higher LAND ALT to maintain 2 psi differential. Above 20,000 feet, select MAN and maintain 2 psi differential.

721, 722, 822

Window 1, 2, 3 or 5:

CRACKED PANE	MAX DIFF PRESSURE	APPROX FLT ALT
Outer	— No Restriction —	
Inner	5 PSI	26,000 FT
Both	2 PSI	15,000 FT

721, 722, 822

Window 4: A failed middle pane usually appears shattered and transparency is virtually lost.

CRACKED PANE	MAX DIFF PRESSURE	APPROX FLT ALT
Outer	— No Restriction —	
Middle	5 PSI	26,000 FT
Both	2 PSI	15,000 FT

APPENDIX B – CABIN ALTITUDE WARNING OR RAPID DEPRESSURISATION NNC

CABIN ALTITUDE WARNING OR RAPID DEPRESSURIZATION

Condition: **One or more of the following conditions:**

- The cabin altitude warning horn sounds
- There is a rapid loss of cabin pressure with airplane altitude above 14,000 feet.

OXYGEN MASKS AND REGULATORS. . . . . ON, 100%

CREW COMMUNICATIONS. . . . . ESTABLISH

PRESSURIZATION MODE SELECTOR. . . . . MAN

OUTFLOW VALVE SWITCH. . . . . CLOSE

If pressurization is restored, continue manual operation to maintain proper cabin altitude.

PASSENGER SIGNS. . . . . .ON

If cabin altitude is uncontrollable:

PASSENGER OXYGEN SWITCH . . . . . .ON

Activate passenger oxygen if cabin altitude exceeds or is expected to exceed 14,000 feet.

EMERGENCY DESCENT . . . . . INITIATE

Accomplish the EMERGENCY DESCENT checklist if the airplane is above 14,000 feet MSL and control of cabin pressure is not possible, or cabin pressure is lost.

APPENDIX C – EMERGENCY DESCENT NNC

EMERGENCY DESCENT

Condition: **Unable to control cabin pressure with airplane above 14,000 feet MSL or conditions require a rapid descent.**

EMERGENCY DESCENT. . . . . ANNOUNCE

The Captain will advise the cabin crew, on the PA system, of impending rapid descent. First Officer will advise ATC and obtain the area altimeter setting.

ENGINE START SWITCHES. . . . . .ON

THRUST LEVERS. . . . . CLOSE

Reduce thrust to minimum or as required for anti-ice.

SPEED BRAKE. . . . . FLIGHT DETENT

DESCENT. . . . . INITIATE

TARGET SPEED. . . . . .Mmo/Vmo

If structural integrity is in doubt, limit speed as much as possible and avoid high maneuvering loads.

LEVEL-OFF ALTITUDE. . . . . LOWEST SAFE ALTITUDE OR 10,000 FT, whichever is higher

711 - 718, 720

CAUTION: When gross weight is greater than 64,864 kgs., speed brake will autostow to the 50% flight detent if airspeed exceeds 320 knots. Do not override autostow function unless airspeed is less than 320 knots.

SPEED BRAKE . . . . . DOWN DETENT

Smoothly lower the SPEED BRAKE lever and level off. Add thrust and stabilize on altitude at desired airspeed.

CREW OXYGEN REGULATORS . . . . . .NORMAL

Flight crew must use oxygen when cabin altitude is above 10,000 feet. To conserve oxygen, position the regulator to NORMAL.

ENGINE START SWITCHES. . . . . .AS REQUIRED

The new course of action is based on weather, oxygen, fuel remaining and available airports. Use of long range cruise may be appropriate.

APPENDIX D – REVISED WINDOW DAMAGE NNC

WINDOW DAMAGE

Condition: **Arcing, delamination, shattered or cracked condition of any flight deck window is observed.**

Seat belt and shoulder harness . . . . . On and locked

If the window is arcing, shattered or cracked:

WINDOW HEAT switch
(affected window) . . . . . OFF

Limit airspeed to 250 knots maximum below 10,000 feet.

If a cracked or shattered condition exists on:

[Option - Windows 4 and 5 installed]
- **Window 1, 2 or 5 inner pane**

[Option - Window 3 heated]
YX600, YX700
- **Window 3 heated inner pane**

[Option - Windows 4 and 5 installed]
- **Window 4 middle or outer pane**

Oxygen masks . . . . . On

Crew communications . . . . . Establish

Passenger signs . . . . . ON

LAND ALT . . . . . 9,000 FT

Descend normally to below 14,000 feet or minimum safe altitude, whichever is higher. Maintain a cabin differential pressure of 2 psi or less.

Plan to land at the nearest suitable airport.

When the cabin differential pressure is 2 psi or less, oxygen masks and shoulder harnesses may be removed.

Sustained flight below 10,000 feet is not recommended due to the greater risk of bird strike.

■■■■

Continued from previous page

[Option - Window 3 not heated]

YX800, YX900

If a cracked or shattered condition exists on window 3 not heated inner and outer panes:

LAND ALT . . . . . 13,000 FT

Descend normally to 13,000 feet or minimum safe altitude, whichever is higher. Maintain a cabin differential pressure of 0 psi.

Shoulder harnesses may be removed.

Sustained flight below 10,000 feet is not recommended due to the greater risk of bird strike.

■■■■

If a cracked or shattered condition exists on:

[Option - Windows 4 and 5 installed]

- **Window 1, 2 or 5 outer pane**

[Option - Window 3 heated]

YX600, YX700

- **Window 3 heated outer pane**

[Option - Window 3 not heated]

YX800, YX900

- **Window 3 not heated inner or outer pane**

[Option - Windows 4 and 5 installed]

- **Window 4 inner pane**

No crew action is needed.

Shoulder harnesses may be removed.

■■■■

If a delamination only condition exists on any window:

No crew action is needed.

Shoulder harnesses may be removed.

■■■■