Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation AO-2008-053

Preliminary

Depressurisation
475 km north-west of Manila, Philippines
25 July 2008

Boeing Company 747-438, VH-OJK

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Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Published by: Australian Transport Safety Bureau
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ISBN and formal report title: see 'Document retrieval information' on page v.

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DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
AO-2008-053	August 2008	38	978-1-921490-65-1

Publication title

Depressurisation, 475 km North-West of Manila, Philippines
Boeing Company 747-438, VH-OJK

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference No.

INFRA - 08244

Acknowledgements

The diagrams presented within Attachments A and B of this report were provided courtesy of the Boeing Company.

Abstract

On 25 July 2008, at 0922 local time, a Boeing Company 747-438 aircraft (registered VH-OJK) with 365 persons on board, departed Hong Kong International airport on a scheduled passenger transport flight to Melbourne, Australia. Approximately 55 minutes into the flight, while the aircraft was cruising at 29,000 ft (FL290), a loud bang was heard by passengers and crew, followed by the rapid depressurisation of the cabin. Oxygen masks dropped from the overhead compartments shortly afterward, and it was reported that most passengers and crew commenced using the masks. After donning their own oxygen masks, the flight crew carried out the ‘cabin altitude non-normal’ checklist items and commenced a descent to a lower altitude, where supplemental breathing oxygen would no longer be required. A MAYDAY distress radio call was made on the regional air traffic control frequency. After levelling the aircraft at 10,000 ft, the flight crew diverted to Ninoy Aquino International Airport, Manila, where an uneventful visual approach and landing was made. The aircraft was stopped on the runway for an external inspection, before being towed to the terminal for passenger disembarkation.

Subsequent inspection of the aircraft by the operator’s personnel and ATSB investigators, revealed an inverted T-shaped rupture in the lower right side of the fuselage, immediately beneath the wing leading edge-to-fuselage transition fairing (which had been lost during the event). Items of wrapped cargo were observed partially protruding from the rupture, which extended for approximately 2 metres along the length of the aircraft and 1.5 metres vertically.

After clearing the baggage and cargo from the forward aircraft hold, it was evident that one passenger oxygen cylinder (number-4 from a bank of seven cylinders along the right side of the cargo hold) had sustained a sudden failure and forceful discharge of its pressurised contents into the aircraft hold, rupturing the fuselage in the vicinity of the wing-fuselage leading edge fairing. The cylinder had been propelled upward by the force of the discharge, puncturing the cabin floor and entering the cabin adjacent to the second main cabin door. The cylinder had subsequently impacted the door frame, door handle and overhead panelling, before falling to the cabin floor and exiting the aircraft through the ruptured fuselage.

The investigation is continuing.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

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.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. 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.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

FACTUAL INFORMATION

The information contained in this preliminary report is derived from the initial investigation of the occurrence. Readers are cautioned that there is the possibility that new evidence may become available that alters the circumstances as depicted in the report.

History of the flight

At 0922 local time (0122 UTC[1]) on 25 July 2008, a Boeing 747-438 aircraft, registered VH-OJK, departed Hong Kong International Airport on a scheduled passenger transport service to Melbourne, Australia. On board the aircraft (operating as flight number QF30) were 346 passengers (including four infants), 16 cabin crew and three flight crew (captain, first officer and second officer).

The flight crew reported that the departure and climb-out from Hong Kong was normal, with the aircraft established at the assigned cruising altitude of 29,000 ft (FL290) by 0942 (0142 UTC).

At 1017 (0217 UTC), the captain and first officer reported hearing a 'loud bang or cracking sound' with an associated airframe jolt. At that time, the autopilot disconnected, and the first officer, who was the pilot flying at the time, assumed manual control of the aircraft. Multiple EICAS[2] messages were displayed, including warnings regarding the R2 door status and cabin altitude.[3] The second officer, who was in the forward crew rest position, returned to the first observer's crew seat and all flight crew donned oxygen masks before completing the 'cabin altitude non-normal' checklist. At that time, the aircraft was approximately 475 km to the north-west of Manila, Philippines.

The cabin crew reported that shortly after the bang was heard, oxygen masks fell from most of the personal service units in the ceiling above passenger seats and in the toilets. Most passengers started using the oxygen masks soon after they dropped. All cabin crew, who were engaged in passenger service activities at the time, immediately located oxygen masks to use. Some crew located a spare passenger mask and sat in between passengers, while others went to a crew jump-seat at an exit, and one used a mask in a toilet.

Approximately 20 seconds after the event, the captain reduced the thrust on all four engines and extended the speed brakes. The first officer commenced the descent while the captain declared a MAYDAY[4] on the Manila flight information region (FIR) radio frequency.

At 1024 (0224 UTC), the aircraft reached, and was levelled at an altitude of 10,000 ft, where the use of supplementary oxygen by passengers and crew was no longer required.

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1 Universal Time, Coordinated (previously Greenwich Mean Time, GMT).

2 Engine Indication and Crew Alerting System.

3 The altitude corresponding to the air pressure inside the aircraft cabin.

4 International call for urgent assistance.

After reviewing the aircraft's position, the flight crew elected to divert and land at the Ninoy Aquino International Airport, Manila, and landing preparations subsequently commenced, including the jettisoning of excess fuel to ensure the aircraft landing weight was within safe limits. The flight crew reported that many system failure messages were displayed, including all three instrument landing systems (ILS), the left VHF omnidirectional radio-range (VOR) navigation instrument, the left flight management computer (FMC) and the aircraft anti-skid braking system.

The crew reported that at all times during the ensuing descent into Manila, they were able to maintain the aircraft in visual flight conditions. With radar vectoring assistance from Manila air traffic control, the captain, who had assumed the pilot flying role, conducted an uneventful approach and landing on runway 06, with a smooth touchdown, full reverse thrust and minimal braking. Emergency services were in attendance after the aircraft was stopped on the runway, after which intercom contact was made with a ground engineer and the aircraft verified as being safe to tow to the airport terminal and disembark the passengers via a terminal airbridge.

Injuries to persons

None of the passengers or crew aboard the aircraft reported any physical injuries to the cabin crew immediately following the depressurisation event, or to the operator's staff upon arrival in Manila.

Damage to the aircraft

Airframe

An initial inspection of the external aircraft surfaces on the ground in Manila revealed the complete loss of the right wing forward leading edge-to-fuselage fairing, with separation occurring along the lines of interconnection between the fairing and fuselage skins (Figure 1). In the area exposed by the fairing loss was an inverted T-shaped rupture in the fuselage skin, with several items from within the forward cargo hold partially protruding from the rupture (Figure 2). The approximate vertical centreline of the skin rupture was positioned at fuselage station[5] (STA) 820, with skin damage extending longitudinally for 79 inches (201 cm), from STA 777 to STA 856. Vertically, the rupture extended for approximately 60 inches (152 cm) between fuselage stringer[6] 31 at the top, to stringer 38 at the lower extent of the damage. While some of the fuselage skin had folded outward and away from the rupture, it was evident that an area of skin and structure equal to approximately one-half of the total ruptured area had separated from the aircraft and was not recovered. On the basis of measurements taken around the ruptured areas, the total area of the skin rupture was estimated at around 1.74 square metres (2,700

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5 Fuselage stations are measured in inches from the front of the aircraft, with the forward surface of the aircraft's nose (radome) located at fuselage station (STA) 90 (Attachment A).

6 Stringers are longitudinally oriented reinforcing sections used to increase the strength and rigidity of the fuselage pressure shell.

square inches). Figure 3 illustrates the extent of the fuselage rupture as viewed from outside the aircraft.

Rearward of the fuselage rupture, several localised areas of scuffing, puncture and scoring were evident along the underside of the aircraft, extending along a diagonal path from the ruptured area rearward toward the left body landing gear (Figure 4). Elongated score marks were also noted extending for several metres around the left side of the rear fuselage – typically around STA 1880 to STA 2000.

Figure 1: Fuselage rupture – external view

Figure 2: Fuselage rupture with protruding cargo

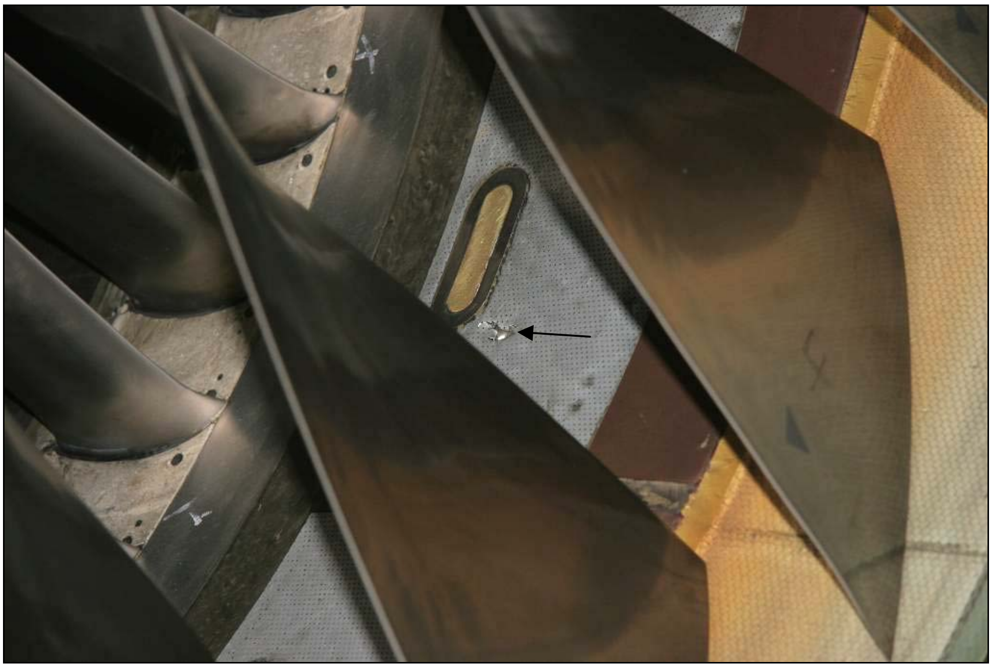
Figure 3: Extent of the fuselage rupture, after removal of further transition fairings

Figure 4. Panel damage to the rear of the rupture site

Engine number-3

Several small pieces of structural honeycomb material of the type comprising the wing leading edge fairing were found trapped around the edges of panels within the left side of the number-3 engine pylon (side facing the rupture). A small indentation and cut was found within the number-3 engine intake acoustic panelling, located immediately inside the plane of rotation of the engine fan (Figure 5). There was no evidence of damage to the fan blades themselves, nor was there any evidence of the ingestion of debris into the engine core.

Figure 5: Damage to acoustic lining (arrowed) behind the number-3 engine fan



Oxygen system

Following removal of all cargo materials and lowering of the hold right-side curtain panels, it was found that the fuselage rupture was aligned with the nominal position of the number-4[7] passenger emergency oxygen cylinder; one of seven such cylinders in a bank along the right side of the hold (Figure 6). A further six cylinders were located in a central location within the ceiling of the cargo hold. The number-4 cylinder was missing from the bank, with the upper support bracket bent downward and both the retaining strap and lower cradle not present (Figure 7). The adjacent number-5 cylinder lower support cradle had been pulled downward and away from the cylinder as a result of the fuselage rupture. However, the upper cylinder mount and strapping remained secure and the cylinder gas connections intact. Each of the passenger oxygen cylinders had three connected stainless steel lines – an overpressure relief vent line, a delivery line and a filling line. The filling and delivery lines were fed through a tee-piece from a common cylinder connection, with a pressure regulator and transducer integral to the assembly (Figure 8). All three lines to the missing number-4 cylinder had fractured, with remnants of the delivery regulator and filling connection fittings remaining attached to their respective lines. Close examination of all exposed connections, fittings and lines showed no evidence of heating, sooting or discolouration that might have suggested localised combustion had occurred within or in proximity to the cylinder and its connections. Similarly, all structural, panel and cargo surfaces that surrounded the fuselage rupture showed no evidence of heating or damage associated with combustion effects. The pressure gauges on all 12 remaining

7 Cylinders were numbered (for the purposes of this investigation) from the front of the cargo hold.

passenger oxygen cylinders showed all to have been exhausted i.e. zero internal pressure remaining.

Figure 6: Forward cargo hold wall with remaining six oxygen cylinders

Figure 7: Fuselage rupture coincident with mounting position of the number-4 oxygen cylinder

Figure 8: Number-5 oxygen cylinder adjacent to fractured fittings and lines from the number-4 cylinder

Cabin – R2 door

The R2[8] door into the aircraft's main cabin was located directly above the fuselage rupture (at STA 830). An external panel located between the two door hinges showed localised outward bulging from a point immediately below the upper hinge, with the forward edge of the panel raised above the surrounding fuselage skin (Figure 9). The main external door handle was in the fully closed position, however the upper and lower door gates[9] were partially retracted.

Within the aircraft, the cabin around the R2 door had sustained substantial damage and disruption (Figure 10). The cabin floor to the left and immediately inside the R2 door frame had sustained an impact that created a single circular perforation approximately 20 cm (8 inches) in diameter, located immediately above the number-4 oxygen cylinder position (Figure 11). Fragments of the cabin flooring and covering extended down into the hole. Above the hole, the forward partitioning panel between the door and the row 26J,K seats showed an elongated green coloured abrasion, leading upward to an area of impact damage at the mid-height position of the forward R2 door frame (Figure 12). The door escape slide shroud (bustle) also showed vertically-oriented scoring and green smear marks along the corner and forward facing surface. The portable walk-around oxygen cylinder normally located in an alcove just inside the R2 door was not present, and was not accounted for in a subsequent search of the aircraft.

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8 The R2 door was the second main cabin door on the right side of the aircraft.

9 The cabin door gates are flap-like panels at the top and bottom of the door that are retracted by the door opening mechanism, to allow the door to move outward through the door frame opening.

Figure 9: Cabin R2 door – damage to external panelling

Figure 10: Interior of R2 door and cabin – location of floor hole arrowed

Figure 11: Hole in cabin floor – viewed from position of number-4 oxygen cylinder

Figure 12: Door frame damage, green paint smear and rotated R2 door handle

The internal door handle was found in approximately the one-o'clock position (looking from inside), with the turned-in handle end embedded into the door lining material. That position was consistent with a movement through approximately 120 degrees from the fully-closed (locked) position. A 180 degree handle movement represented the fully open position. The downward facing surfaces of the handle end (when the door is in the locked position) showed damage and abrasion consistent with impact against another object. Inspection of the internal door systems showed the handle shaft had fractured and the actuating cam plate and retainer had pulled away from its associated mechanism (Figure 13), allowing the handle to rotate freely. As such, the handle position as observed inside the cabin was not indicative of the actual door security.

Above the R2 door within the cabin, the overhead panelling, fixtures and utility storage compartments had sustained extensive impact damage. The panels above the door frame had been pushed inward, exposing the overhead structure and pressure reservoir for the door emergency power assist opening system (EPAS, Figure 14). Amongst the impact damage, it was observed that an unusually uniform semi-circular section had been forcibly cut from the panelling and access door (Figure 15), with the cut-out section later recovered from above the damaged storage compartment casing. The diameter of the cut-out region closely matched that of the passenger oxygen cylinders (Figure 16). Adjacent to the cut-out opening was a semi-circular area of crushing damage to a partitioning panel (Figure 17); the damage being of a similar diameter to the cut-out section. A light fitting, normally present in the overhead panels had sustained upward crushing damage and presented clear green paint smears of a similar colouration to the marks on the partition panel and door bustle.

Various items of debris were found around the aircraft cabin in the vicinity of the R2 door. Of note, this included fragments of the number-4 oxygen cylinder valve handle, the valve pressure relief assembly and the valve body itself. A fragment of the valve body was also recovered from within the damaged area on the door frame. A thorough search of the cabin and overhead ceiling void space failed to locate any part of the number-4 oxygen cylinder itself.

Figure 13: R2 door panel underside – fractured shaft and separated plate

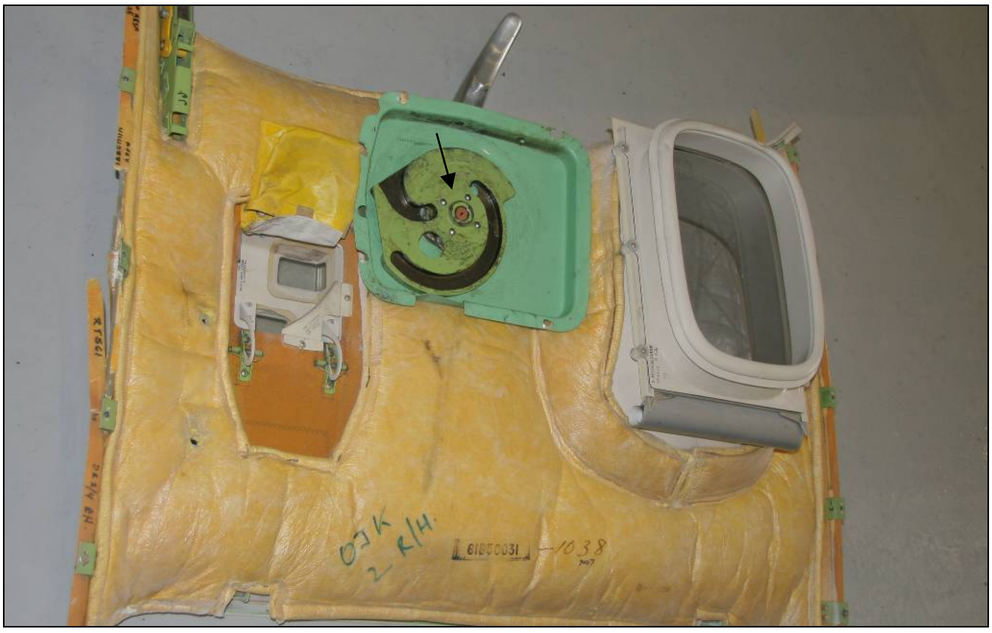

Figure 14: Damage above R2 door, exposing the EPAS cylinder (arrowed)

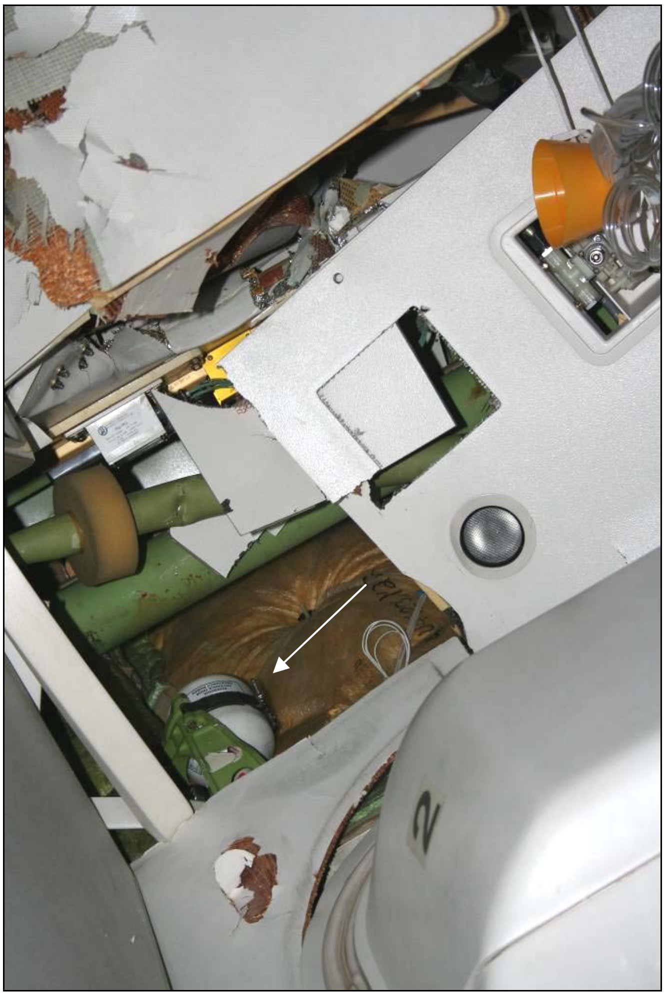

Figure 15: Cut-out section found in panels above the R2 door

Figure 16: Panel with cut-out placed against another oxygen cylinder to illustrate the conformance in diameter

Figure 17: Semi-circular damage in partition of compartment above R2 door

Cabin – safety systems

Investigators conducted a comprehensive walk-through examination of the aircraft's cabin and a survey of the safety systems; in particular, the status of the passenger oxygen masks and equipment (Figure 18).

The following preliminary observations were made during that examination:

- there were 353 passenger seats in the aircraft
- 476 passenger oxygen masks had deployed from their overhead compartments
- 426 passenger oxygen masks were pulled down (i.e. activated for use)
- row 53 centre overhead passenger service unit was hanging down
- forward crew rest and customer support manager station masks had not deployed
- the covering on the rear surface of the partition in front of seats 40A,B,C was damaged
- floor pressure relief panels were open at seats 24A (2), 25A, 37K and 54A
- one mask hose was detached from the ceiling fitting at seat 4K (3 masks deployed).

Figure 18: Typical appearance of cabin. Note passenger masks dropped and activated, and those dropped and not activated (arrowed)

Electrical

Numerous electrical cables and cable bundles, routed through the lower aircraft fuselage near the point of rupture, had sustained damage or been severed by the rupture event. Approximately 86 discrete conductors from six separate bundles had been affected.

Flight control

Both right side (first officer's) aileron control cables, routed along the right side of the fuselage above the passenger oxygen cylinders, had been fractured during the rupture event. All separated cable ends showed the irregular splaying and unwinding of the cable wires; characteristic of a tensile overstress failure.

Other damage

Cargo

The forward hold of the aircraft contained both containerised and palletised cargo. All passenger baggage was located within conventional metal containers positioned forward of the point of rupture. None of the containers within the hold showed evidence of damage or other markings that could be associated with the rupture event. The cargo adjacent to the fuselage rupture was a plastic wrapped and netted pallet of general freight in cardboard boxes and similar. The cargo packed along the side closest to the rupture had been pulled towards the opening, with several items becoming lodged within, and protruding from, the void (Figure 19). Items packed near to the fuselage rupture showed varying degrees of forced impact type damage and a section of aluminium structure from the hold framework was recovered from amongst the packaging. There was no evidence of an explosive event having originated from within the cargo itself, and a review of the cargo manifests showed no items that could be considered capable of causing or contributing to such an event. Reconciliation of the recovered cargo by the freight service provider accounted for all items on the manifest.

Figure 19: Cargo pallet adjacent to fuselage rupture (view looking to the rear)

Personnel information

Table 1 summarises the operational qualifications and experience of the flight crew at the time of the occurrence.

Table 1: Flight crew qualifications and experience

	Captain	First Officer	Second Officer
Licence Category	ATPL	ATPL	ATPL
Instrument rating	Command	Command	Co-pilot
Last Class-1 medical	27 Sep 2007	20 May 2008	27 Jun 2008
Total flying hours	15,999	12,995	4,067
Total on 747-400	2,786	5,736	2,292
Total last 30 days	67h 48m	96h 57m	67h 48m
Total last 90 days	221h 54m	251h 27m	137h 33m

Aircraft information

Aircraft general

Aircraft type	Boeing Company 747-438
Serial number	25067
Year of manufacture	1991
Registration	VH-OJK
Certificate of Airworthiness	SY 45 valid from 17 June 1991
Certificate of Registration	last issued on 24 October 2005
Total airframe hours	79,308
Total airframe cycles	10,419
Last 'A' maintenance check	13 June 2008, at 78,967 h, 10,357 cyc
Last 'D' maintenance check	9 April 2004, at 58,367 h, 8,173 cyc

Cabin door

All main cabin doors of the 747-400 aircraft type were designed as outward-opening 'plug doors'. A plug door is designed to be physically larger than the doorway opening, and mates with the frame around the full circumference when in position. It is designed to increase the security of the pressurised fuselage, with pressurisation loads serving to force the door more tightly against the frame. Retractable gates at the top and bottom of the door serve to allow it to move inward and then sideways through the door frame during the opening and closing process when the aircraft is not pressurised. The plug door design provides for a level of protection against inadvertent or intentional attempts to open the door while the aircraft is in flight. A latch mechanism holds the door in the closed position when the aircraft is not pressurised.

Flight control system

The Boeing 747-400 flight control system was a hydraulically-assisted mechanical arrangement, with inputs from the primary cockpit controls being translated to the control surface actuating systems via cables. The systems were designed to provide complete duplication and redundancy between the captain and first officer's controls, such that the failure of any particular system would not lead to a loss of functionality affecting aircraft controllability. Basic certification specifications for all modern transport category aircraft require this behaviour by design. In respect of the first officer's aileron control cables that were severed in the occurrence; those were duplicated by the captain's system, the cables from which were routed along the opposite (left) side of the forward cargo hold. Interlinks between the aileron systems provided the necessary redundancy in this instance, ensuring the continued safety of flight after the event.

Oxygen systems

The 747-438 aircraft was equipped with three separate supplemental breathing oxygen systems. Use of oxygen by passengers and crew is necessary if cabin pressurisation is lost during high-altitude flight. A diluter-demand[10] system provided oxygen to each flight crew station and an independent, continuous flow[11] system served the passenger cabins, crew rest areas, toilets and cabin crew stations. Portable oxygen equipment was also stored throughout the passenger cabins for medical and walk-around use. All three systems were of the pressurised gaseous storage type, with no chemical oxygen generators employed on the aircraft.

The passenger oxygen system consisted of thirteen high-pressure (1,850 psi / 12,755 kPa) steel cylinders, each with an integral shut-off valve, pressure gauge and over-pressure protection system (frangible disk). A coupling connected each cylinder to an electrical pressure transducer and pressure reducer. The outlet of each cylinder fed a common supply line, which was routed through three continuous flow control units connected in parallel. The flow control units served to control the flow of oxygen to the passenger mask distribution manifold, and to regulate that flow according to the cabin altitude. Seven of the cylinders were located along the right side of the forward cargo hold; the remainder positioned within the void space between the cargo hold ceiling and the main cabin floor (Attachment B).

Due to periodic removal and replacement for maintenance or replenishment purposes, the installed cylinders were of varying ages and serial numbers. Table 2 presents general details of the complement of passenger oxygen cylinders fitted to VH-OJK at the time of the occurrence.

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10 A diluter-demand oxygen system provides diluted or 100% oxygen flow as required by the breathing action of the user.

11 A continuous flow oxygen system delivers a constant stream of oxygen to the user, once the system and mask have been activated.

Table 2: Details of the passenger oxygen cylinders fitted to VH-OJK at the time of the occurrence

Location	Serial No.	Manufactured date	Fitted to aircraft date
Right side #1	240341	Feb 92	16 Jun 07
Right side #2	ST30395	Oct 01	14 Jun 08
Right side #3	ST20539	Apr 01	19 Jan 07
Right side #4	**535657**	**Feb 96**	**14 Jun 08**
Right side #5	666845	Mar 99	01 Mar 06
Right side #6	240293	Dec 91	07 Jan 08
Right side #7	239949	Nov 91	07 Jan 08
R Fwd O/H	883198	May 89	07 Jan 08
L Fwd O/H	686764	May 98	01 Sep 06
R Mid O/H	805949	Sep 04	17 Nov 07
L Mid O/H	686716	Jun 99	28 Sep 05
R Aft O/H	679454	Apr 99	07 Jan 08
L Aft O/H	71505	Jan 91	22 Jul 07

Cylinder information

All passenger oxygen cylinders installed in VH-OJK were of a single piece, heat-treated alloy steel construction. The missing (presumed failed) oxygen cylinder, part number 801307-00[12], serial number 535657, was one of a batch of 94 cylinders manufactured in February 1996 to the DOT[13] 3HT1850 specification. The cylinders measured 22.8 cm outside diameter by 75.1 cm long (8.98 inches x 29.56 inches) and had a minimum 2.87 mm (0.113 inch) wall thickness.

Flight recorders

The aircraft was fitted with three flight recorders:

- cockpit voice recorder (CVR)
- flight data recorder (FDR)
- quick-access recorder (QAR).

The CVR and FDR are required by regulation to be installed on certain types of aircraft. Information recorded by the CVR and FDR is stored in 'crash-protected' modules.

The QAR is an optional recorder that the operator has chosen to fit to all their B747-400 aircraft. Information recorded by the QAR is not crash-protected. As the name suggests, QARs allow quick access to flight data whereas FDR's require specialist downloading equipment. The parameters that are recorded by an FDR are

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12 Equivalent Boeing part number 60B50087-7.

13 United States Department of Transportation.

defined by regulatory requirements. However QAR systems can be configured by an airline to record different and, in most cases, more parameters than the FDR system. Airlines routinely use QAR data for engineering system monitoring and fault-finding, incident investigation and flight operations quality assurance programs.

Recording system operation

CVR system

The CVR records the total audio environment in the cockpit area. This includes crew conversation, radio transmissions, aural alarms, control movements, switch activations, engine noise and airflow noise. The CVR installed in VH-OJK retained the last 2 hours of information in solid-state memory, operating on an endless-loop principle.

CVR systems are designed to operate even when the aircraft is on the ground with the engines shutdown. This allows investigators access to important crew conversation or checklist actions before the first engine is started for takeoff or after the last engine is shutdown after landing. The disadvantage is that valuable audio information is quickly overwritten following a non-catastrophic accident or serious incident, where there is a significant interval between the occurrence and when the flight is completed and electrical power is removed from the CVR.

FDR system

The FDR records aircraft flight data and, like the CVR, operates on an endless-loop principle. The recording duration of the FDR fitted to VH-OJK was 25 hours; the FDR typically records when at least one engine is operating and stops recording when the last engine is shutdown. The FDR installed in VH-OJK recorded approximately 300 parameters and used a magnetic tape as the recording medium.

QAR system

Like the FDR, the QAR records aircraft flight data. The QAR installed in VH-OJK stored data on a removable magneto-optical disk with a capacity of 230 Mb and approximately 500 recorded parameters. Airlines balance the logistics of handling large quantities of QAR disks with the benefits of obtaining the data as soon as possible after a flight has occurred. Typically, most airlines will leave a disk inserted in the QAR for several days until the aircraft returns to a suitable maintenance base.

The QAR system installed on VH-OJK was configured to enter a ‘sleep’ mode once a period of stable cruise had been detected. Once a climb or a descent was detected, the QAR would resume recording until a further period of cruise was detected. As B747-400 aircraft are typically used on long-range flights, using this sleep mode technique reduced the amount of data that was recorded per flight and increased the number of flights that could be recorded on a single disk. Worldwide experience over many decades has shown that the take-off and landing phases of flight have the highest risk and these periods are continuously recorded using this ‘sleep’ mode technique.

Recorder recovery

The CVR, FDR and QAR disk were removed from the aircraft in Manila under the control of the Australian Transport Safety Bureau (ATSB) and sent to the operator’s safety department in Sydney. They were received on Sunday 27 July 2008. Permission was given by the ATSB for the operator to replay the QAR disk and a copy of the QAR data was provided to the ATSB.

The CVR and FDR were quarantined and sent to the ATSB technical analysis laboratories in Canberra. They were received on 28 July 2008. The CVR was downloaded on 28 July 2008 and the FDR was downloaded on 29 July 2008.

Results

CVR

The entire 2 hours of recorded audio was successfully downloaded by ATSB investigators in Canberra. Analysis of the audio showed that the oldest information retained by the CVR related to aircraft operation while cruising at 10,000 ft, after the emergency descent had already taken place. A comparison with the FDR information showed that the start of the CVR audio occurred 30 minutes and 41 seconds after the depressurisation event had occurred.

Of the 2 hours of CVR audio, 24 minutes covered flight time including the approach and landing at Manila. The remaining audio covered ground operations including the aircraft being towed from the runway to the gate and time with the aircraft stationary at the gate.

FDR

The tape was removed from the FDR by ATSB investigators in Canberra and downloaded. The FDR had recorded data from the following flights:

23 July 2008: Singapore – London

24 July 2008: London – Hong Kong

25 July 2008: Hong Kong – Manila

Continuous data from engine start on the ground in Hong Kong until engine shutdown on the runway in Manila, was successfully recovered. The FDR data was used to produce a sequence of events and plots (Attachment C).

QAR

The QAR disk was replayed by the operator. As an empty disk had been installed in the QAR at Sydney on 23 July 2008, flight data from five flights was successfully recovered. The flights recorded were:

23 July 2008: Sydney – Melbourne

Melbourne – Singapore

Singapore – London

24 July 2008: London – Hong Kong

25 July 2008: Hong Kong – Manila

Analysis of the QAR data, in conjunction with FDR data, showed that the QAR recorded continuously from engine start on the ground in Hong Kong until 0212:28 UTC when, as expected, the QAR entered 'sleep' mode while the aircraft was in cruise at FL290. The depressurisation event occurred 4 minutes and 48 seconds later. Four seconds after the event, the QAR resumed recording data.

Sequence of events

The flight

The following sequence of events table was prepared from data obtained from the aircraft's flight recorders.

Table 3. Occurrence flight sequence of events

Time (UTC) (hh:mm:ss)	Time relative to event (hh:mm:ss)	Event:
01:22:12	-00:55:04	Takeoff at Hong Kong
01:42:30	-00:34:46	Aircraft reached top of climb FL290
02:12:28	-00:04:48	QAR entered 'sleep' mode and stopped recording
02:17:16	**0:00:00**	**Depressurisation event**
02:17:17	0:00:01	Autopilot (Right) disengaged
02:17:19	0:00:03	Cabin pressure warning commenced
02:17:20	0:00:04	QAR resumed recording data
02:17:38	0:00:22	Speed brake extended, engine thrust reduced
02:17:43	0:00:27	L & R isolation valves change to closed
02:17:54	0:00:38	Aircraft left FL293 on descent
02:17:57	0:00:41	A minimum cabin pressure of 5.25 psi was recorded[14]
02:18:43	0:01:27	Autopilot (Centre) engaged

14 This corresponds to a cabin altitude of 25,900 ft.

Time (UTC) (hh:mm:ss)	Time relative to event (hh:mm:ss)	Event:
02:19:09	0:01:53	Autothrottle disconnected
02:22:50	0:05:34	Cabin pressure warning ceased
02:23:09	0:05:53	Aircraft descended through 11,000 ft
02:23:48	0:06:32	Aircraft altitude reached 10,000 ft
02:29:40	0:12:24	Captain's NAV SEL changed to right FMC
02:47:57	0:30:41	Start of CVR audio
02:56:11	0:38:55	Aircraft left 10,000 ft on descent
03:09:58	0:52:42	Autopilot (Centre) disengaged
03:11:56	0:54:40	Aircraft touched down at Manila
03:17:38	1:00:22	No. 3 engine shutdown on runway
03:19:10	1:01:54	Remaining engines shutdown on runway
03:26:53	1:09:37	Park brake released for tow
04:01:12	1:43:56	Chocks on
04:51:06	2:33:50	CVR shutdown

Cylinder event

On the basis of the physical damage found with the aircraft forward cargo hold and cabin, it was evident that the number-4 passenger oxygen cylinder had sustained a failure that allowed a sudden and complete release of the pressurised contents. The rupture and damage to the aircraft fuselage was consistent with being produced by the energy associated with that release of pressure. Furthermore, it was evident that as a result of the cylinder failure, the vessel had been propelled upward, through the cabin floor and into the cabin space. Damage and impact witness marks found on the structure and fittings around the R2 cabin door showed the trajectory of the cylinder after the failure event.

Figures D1 – D7 (Attachment D) illustrate the likely trajectory of the cylinder. The graphics represent a cross-sectional view through the aircraft at the position of the R2 main cabin door (STA 830).

ONGOING INVESTIGATION ACTIVITIES

Survival factors

A cabin safety / survival factors investigation will examine the serviceability and functionality of the cabin oxygen apparatus and other cabin safety equipment, cabin crew actions, and passenger actions and problems. The investigation has interviewed all 16 of the cabin crew about their experiences, and a review of cabin crew procedures will be conducted.

The investigation is also conducting a survey of all passengers on the flight. The results of this survey will help the investigation determine what occurred and enable the investigation to document passenger and crew actions, equipment issues, and whether there were any resulting injuries. The effects of the damage sustained by the oxygen system on its capacity to function adequately and for a sufficient period will also be investigated. The survey will also help determine if any improvements in equipment design or crew procedures are needed to enhance safety.

The survey has been emailed or posted to passengers where the ATSB could locate contact details. Passengers who have not received a survey but who would like to receive one are requested to provide an email or postal address to the ATSB (email aviation.investigation@atsb.gov.au or phone +61 2 6257 4150 (from overseas) or 1800 020 616 (within Australia).

Cylinder failure

The ongoing engineering investigation into the apparent oxygen cylinder failure will focus on (but not be limited to) the following:

- cylinder design, manufacturing methods and type testing procedures
- manufacturing quality control processes and results
- modes and mechanisms of cylinder failure
- historical oxygen and pressurised cylinder failure experiences, civil and military, aviation and industrial
- cylinder degradation mechanisms
- the adequacy and efficacy of inspection, maintenance and repair processes, procedures and equipment prescribed by the manufacturer and implemented by maintenance organisations
- cylinder filling processes and procedures.

As the failed cylinder was not recovered, the ATSB is currently working with the aircraft manufacturer, other aircraft operators and the oxygen cylinder manufacturer, to obtain samples of cylinders from the same manufacturing batch as the failed item, to facilitate the ongoing investigation of all relevant issues.

Flight recorders

Examination of CVR, FDR and QAR information is ongoing and will include the following:

- Analysis of CVR audio regarding crew actions, aircraft handling and crew/cabin communications during the approach and landing at Manila.
- Analysis of QAR data to assist in identifying secondary damage from the oxygen bottle failure and the effects of that damage to aircraft systems and aircraft handling.
- Analysis of FDR data to produce a detailed sequence of events and assist in identifying secondary damage from the oxygen bottle failure and the effects of that damage to aircraft systems and aircraft handling.
- A review of the operator’s procedures for preserving a CVR recording following a serious incident or non-catastrophic accident.

SAFETY ACTION

Aircraft operator

On 27 July (2 days following the VH-OJK event), the aircraft operator, in agreement with the Civil Aviation Safety Authority (CASA), commenced a fleet-wide program of detailed visual inspections of its Boeing 747 oxygen system installations. The ATSB was advised that those inspections were completed by 1 August.

The operator has also completed a preliminary internal review of the event, addressing the crew and passenger response, the emergency passenger oxygen system operation, supplementary passenger oxygen requirements, and the functionality of the depressurisation emergency announcement system operation.

ATSB assessment of action

The ATSB has requested a copy of the findings of the inspection program and review from the aircraft operator and will consider any issues that may have been identified, in its ongoing investigation of the event.

ATSB safety action

It is acknowledged that any corrective or precautionary action undertaken in response to a safety occurrence should be justifiable in terms of established or probable facts. However, in view of the nature of the depressurisation event and the implication of a possible mechanism or condition that could affect the structural integrity and safety of other oxygen cylinders used in the aviation environment, the ATSB draws attention to the following advisory notices, on the basis of prudence, until such time that the mechanism/s contributing to the cylinder failure on board VH-OJK are established and understood.

Safety advisory notice (AO-2008-053-SAN-006)

The Australian Transport Safety Bureau encourages all organisations performing inspection, testing, maintenance and repair activities on aviation oxygen cylinders, to note the circumstances detailed in this preliminary report, with a view to ensuring that all relevant procedures, equipment, techniques and personnel qualifications satisfy the applicable regulatory requirements and established engineering best-practices.

Safety advisory notice (AO-2008-053-SAN-007)

The Australian Transport Safety Bureau encourages other operators of transport category aircraft fitted with pressurised gaseous oxygen systems, to note the circumstances detailed in this preliminary report, with a view to ensuring that all oxygen cylinders, and cylinder installations, are maintained in full accordance with the relevant manufacturer's requirements, statutory regulations, and established engineering best practices.

ATTACHMENT A: AIRCRAFT STATIONS

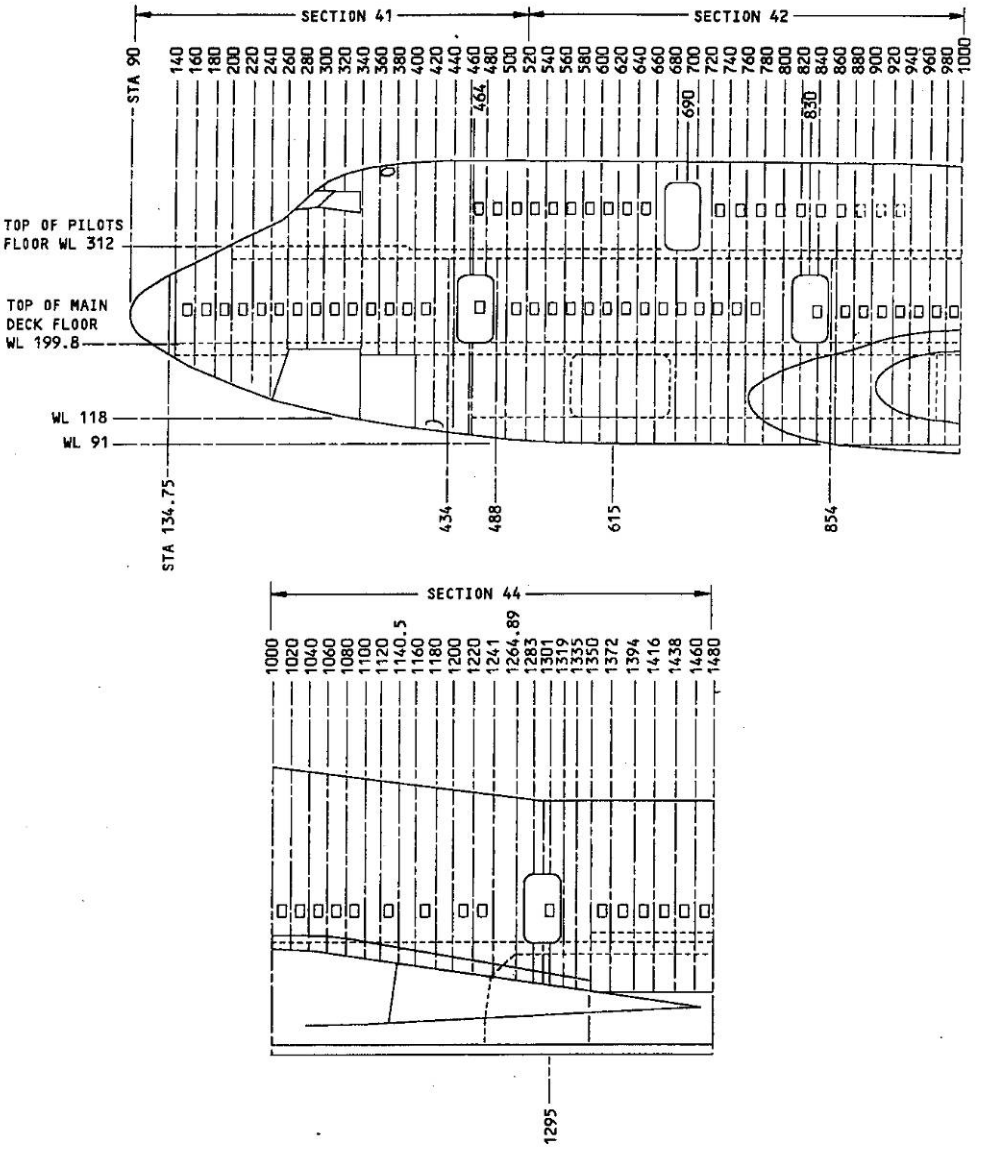
Figure A1: Boeing 747-400 forward fuselage station diagram

BOEING 747

747-400

STRUCTURAL REPAIR MANUAL

REF DWG
65B00004



Fuselage Station Diagram
Figure 1 (Sheet 1)

53-00-00

01 Page 3
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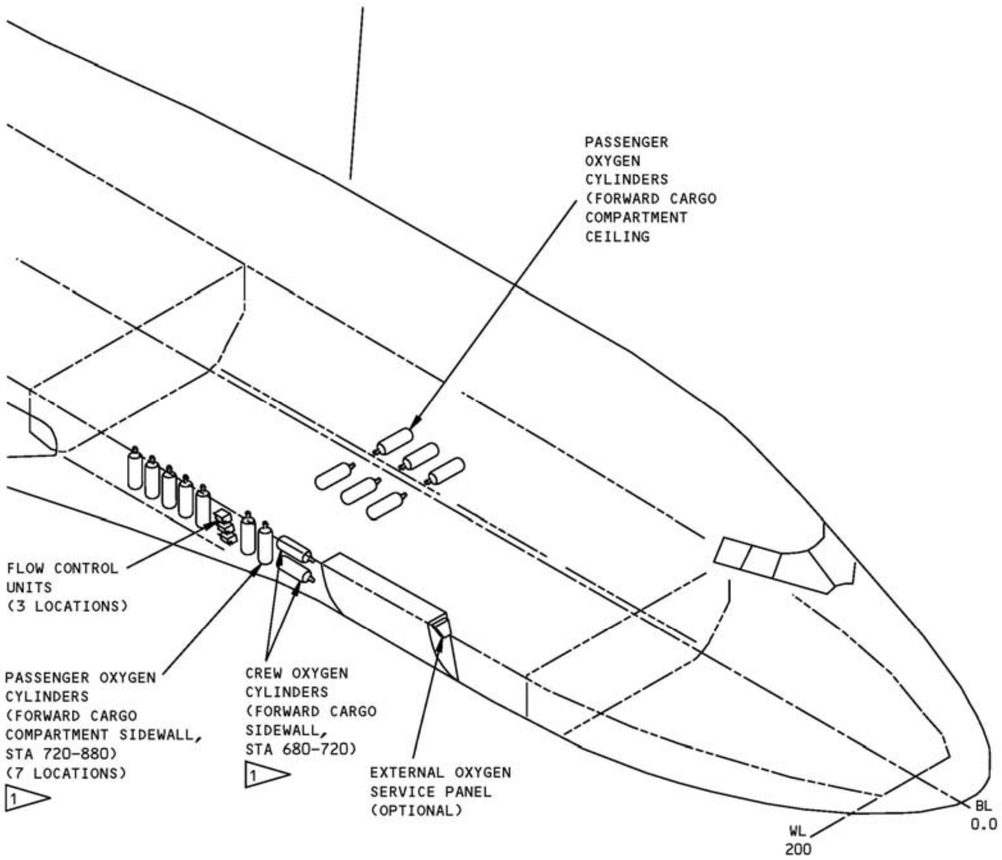
ATTACHMENT B: OXYGEN CYLINDER LOCATIONS

Figure B1: Typical cylinder locations in the Boeing 747-400 aircraft

BOEING

747-400
AIRCRAFT MAINTENANCE MANUAL



1 MAXIMUM SHOWN ACTUAL QUANTITIES MAY VARY.

Oxygen Supply System
Figure 1 (Sheet 2 of 2)/35-40-00-990-801-001

EFFECTIVITY
QAN 051, 052, 201-999

D633U101-25

35-40-00
Config 1
Page 4
Feb 18/2006

ATTACHMENT C: FLIGHT DATA RECORDER PLOTS

Figure C1: Data plot for complete flight duration

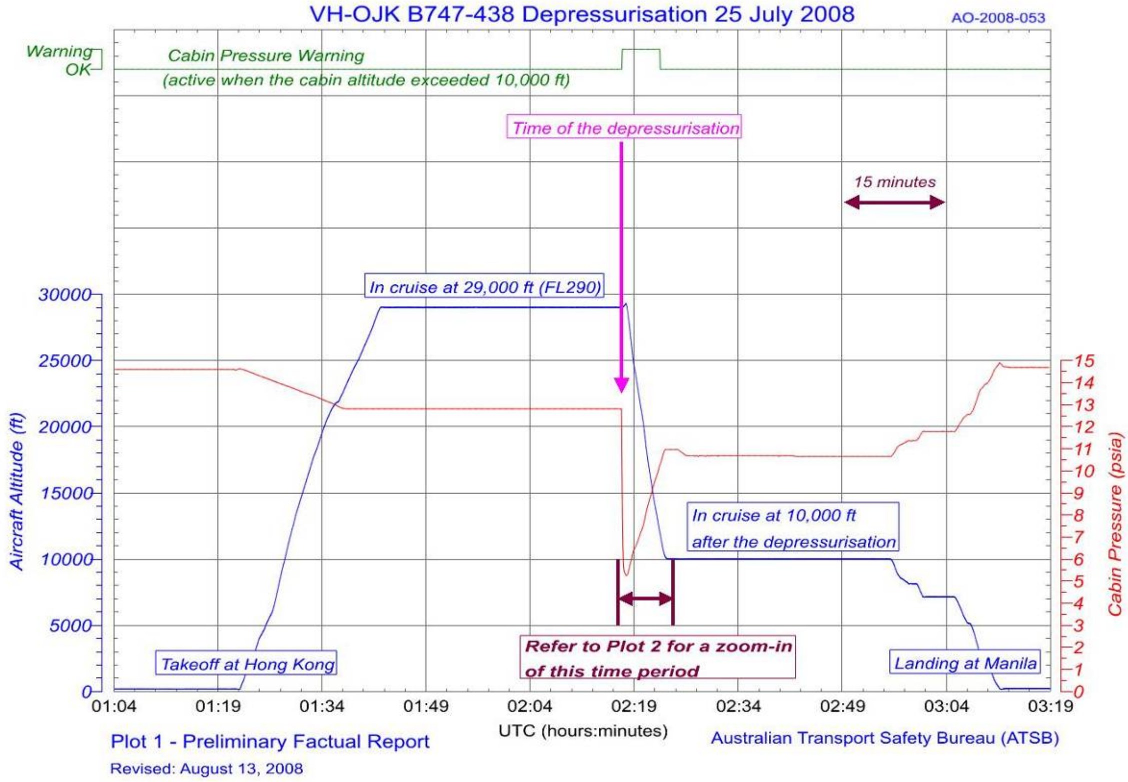
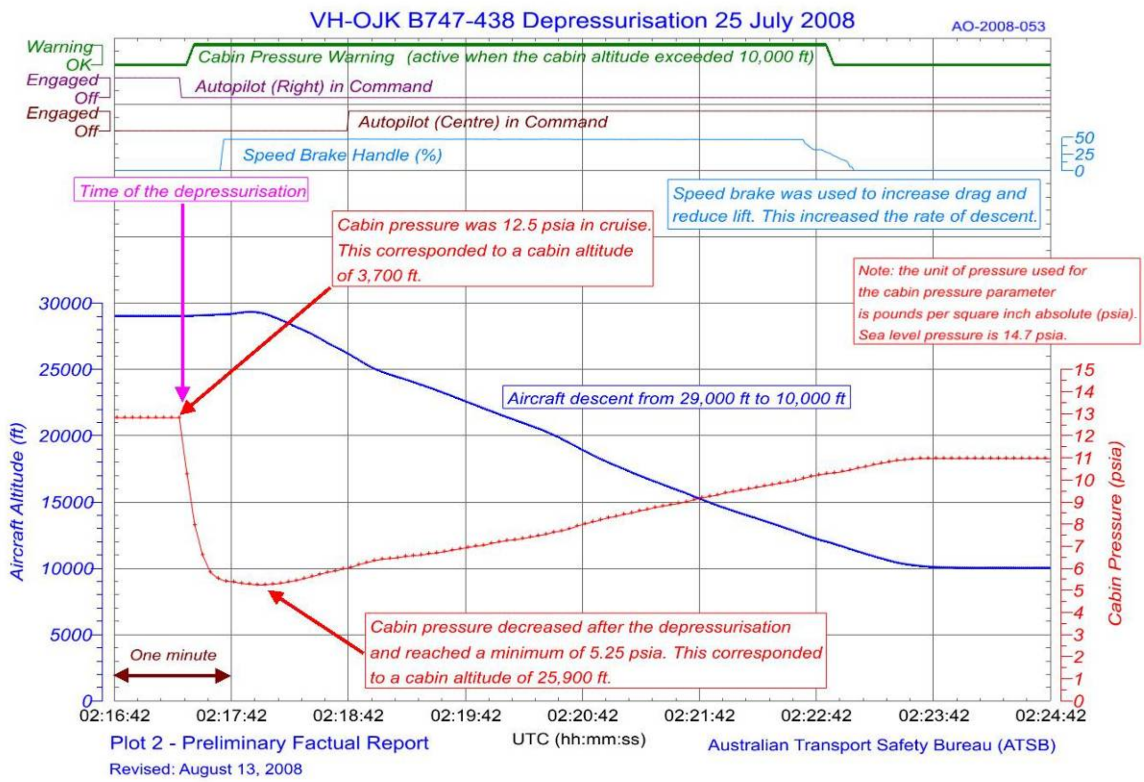
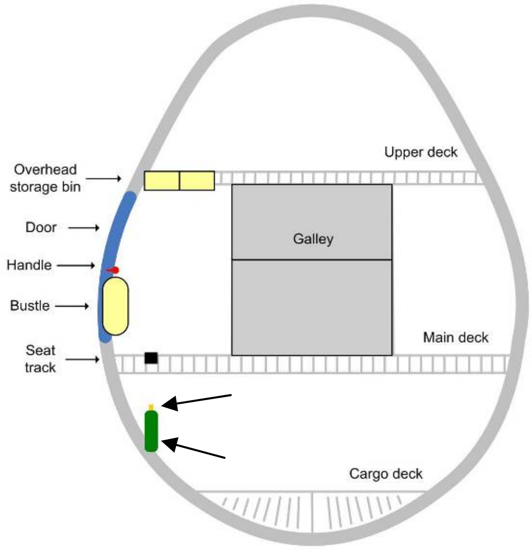


Figure C2: Data plot for the depressurisation event

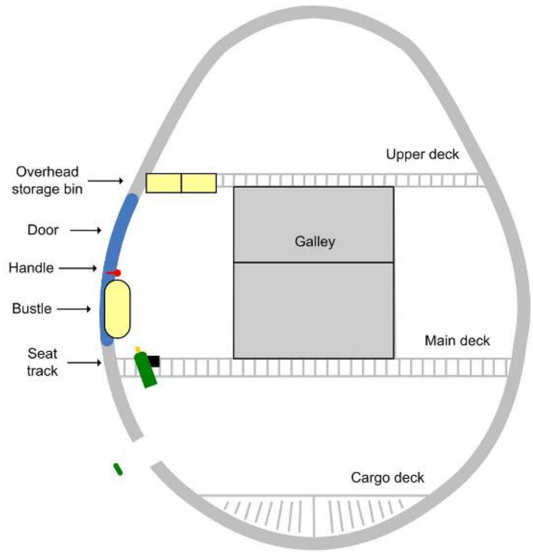


ATTACHMENT D: PROBABLE OXYGEN CYLINDER TRAJECTORY

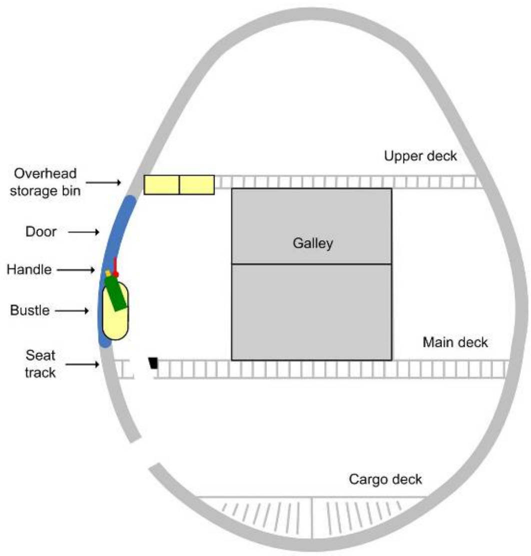
Figures D1 – D7: **Cross-sectional view through aircraft fuselage at the R2 cabin door location**



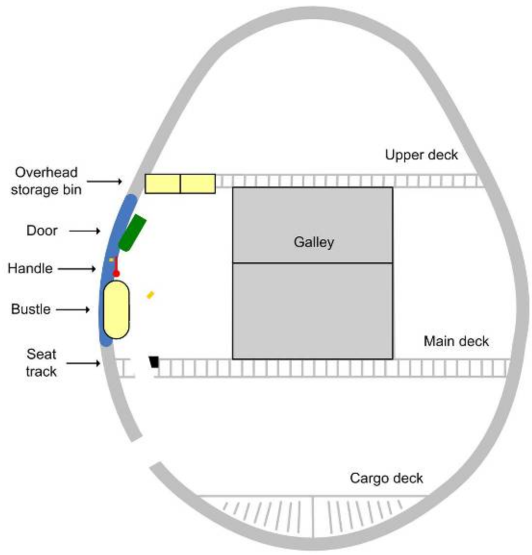
1. Normal arrangement (Oxygen cylinder and valve arrowed)



2. Cylinder failure produces fuselage rupture, with bulk of the cylinder length propelled upward through the cabin floor. See Figure 11.

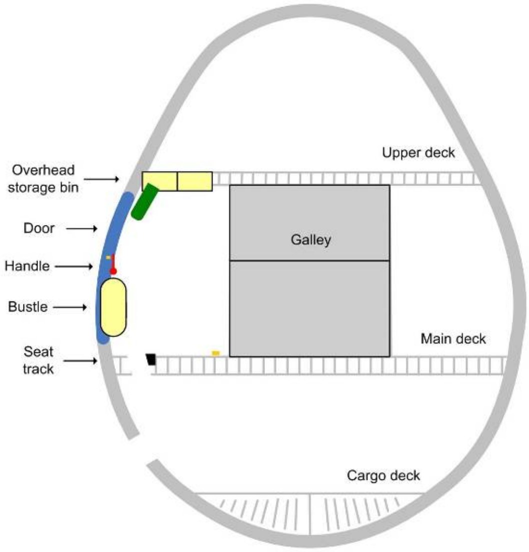


3. Cylinder impacts R2 door frame and internal door handle. See Figures 10 & 12.

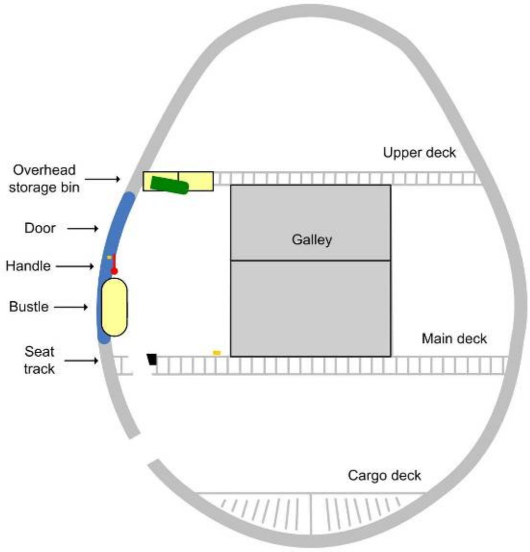


4. Door frame impact breaks off cylinder valve and causes cylinder to invert while continuing to travel upward.

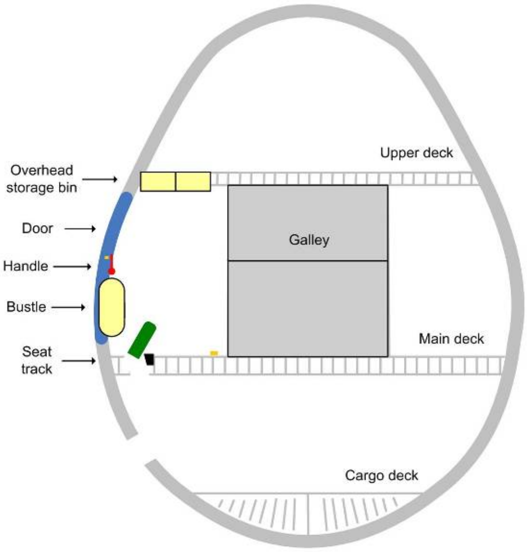
Probable oxygen cylinder trajectory (continued)



5. Cylinder impacts overhead panelling end-on, producing circular cut-out type damage. See Figures 14-16.



6. Still rotating cylinder impacts overhead storage bin, producing semi-circular crushing damage. See Figure 17.



7. Cylinder falls to cabin floor and exits the aircraft through the ruptured fuselage.

Australian Government

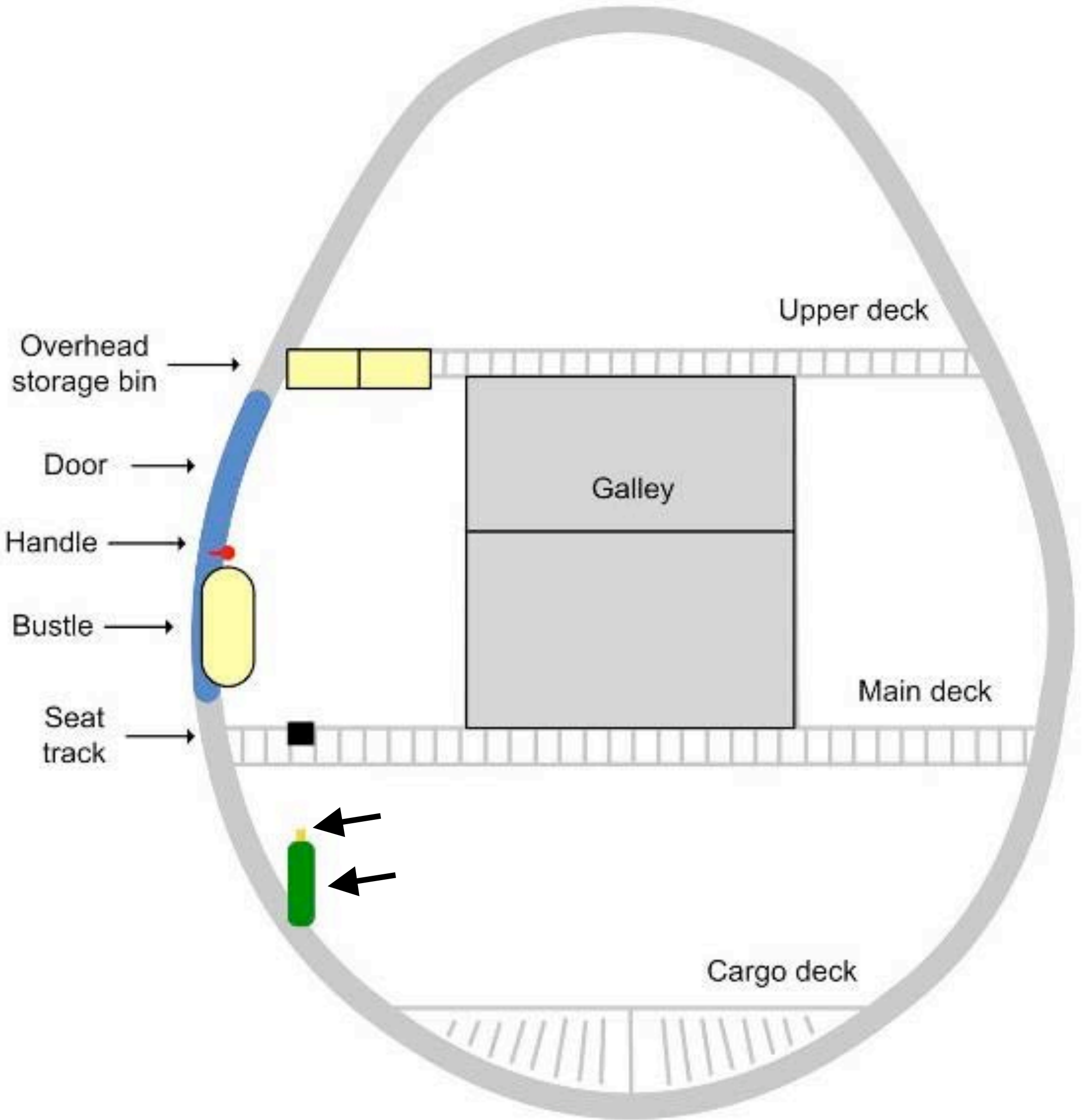
Australian Transport Safety Bureau

Depressurisation
475 km north-west of Manila, Philippines
25 July 2008
Boeing Company 747-438, VH-OJK

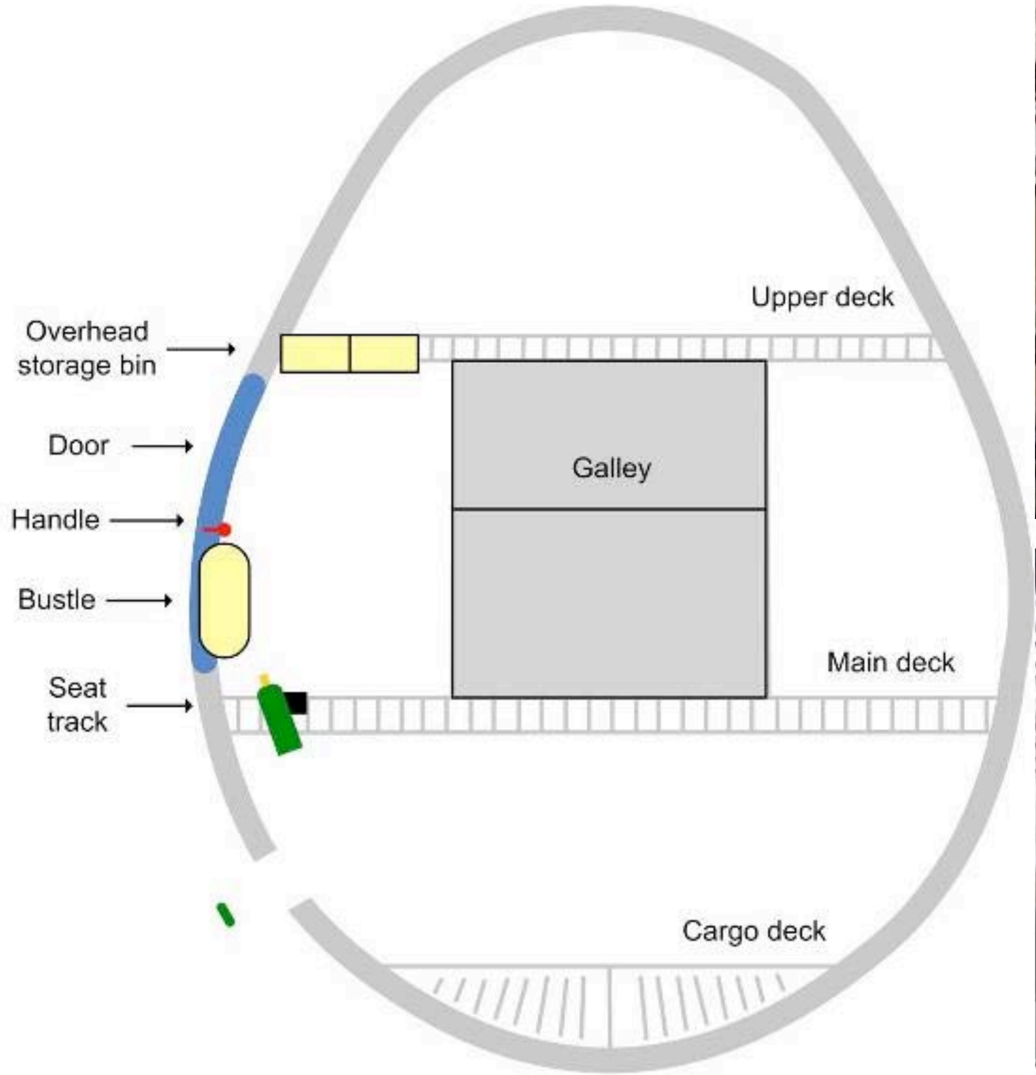
Safe Transport

Released under Section 25 of the *Transport Safety Investigation Act 2003* as part of ATSB Preliminary Report AO-2008-053

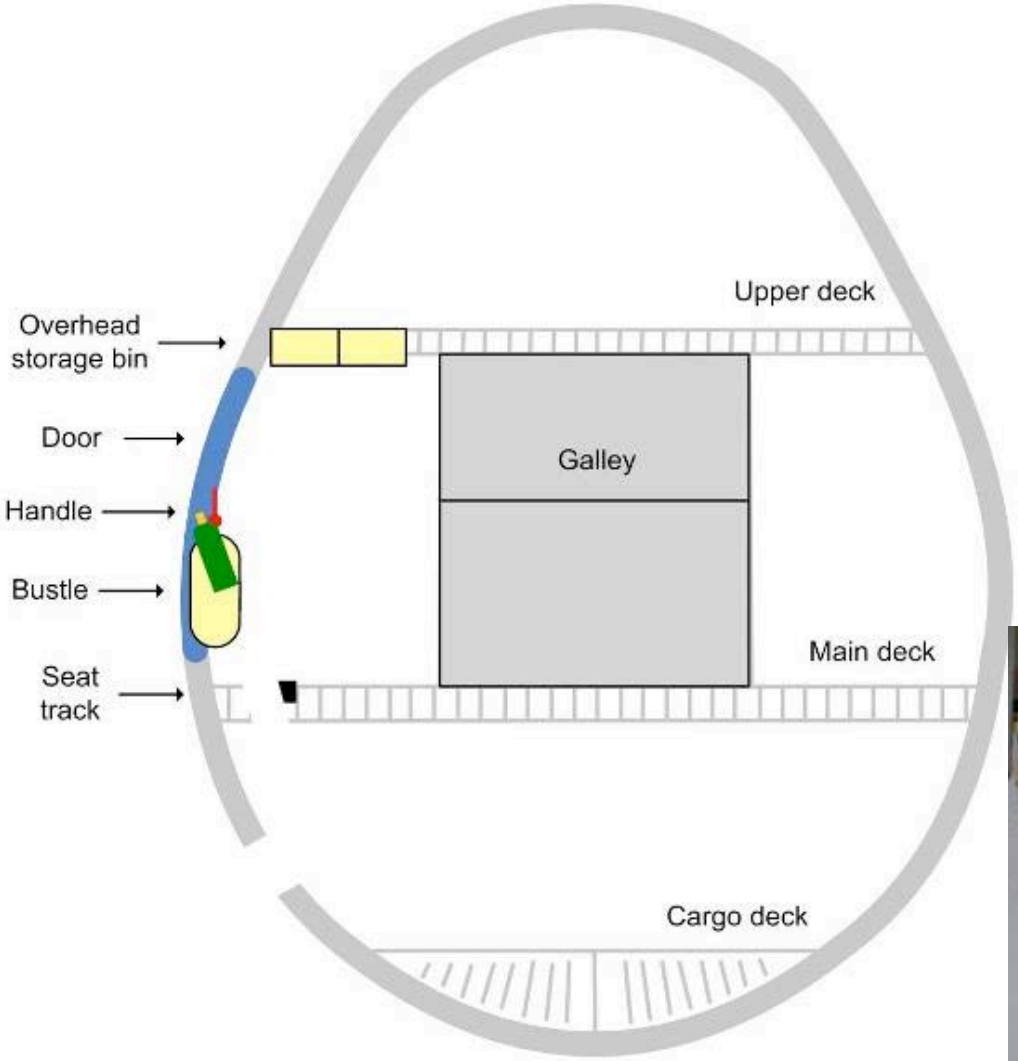
1. Normal arrangement
(Oxygen cylinder and valve arrowed)



2. Cylinder failure produces fuselage rupture, with bulk of the cylinder length propelled upward through the cabin floor.

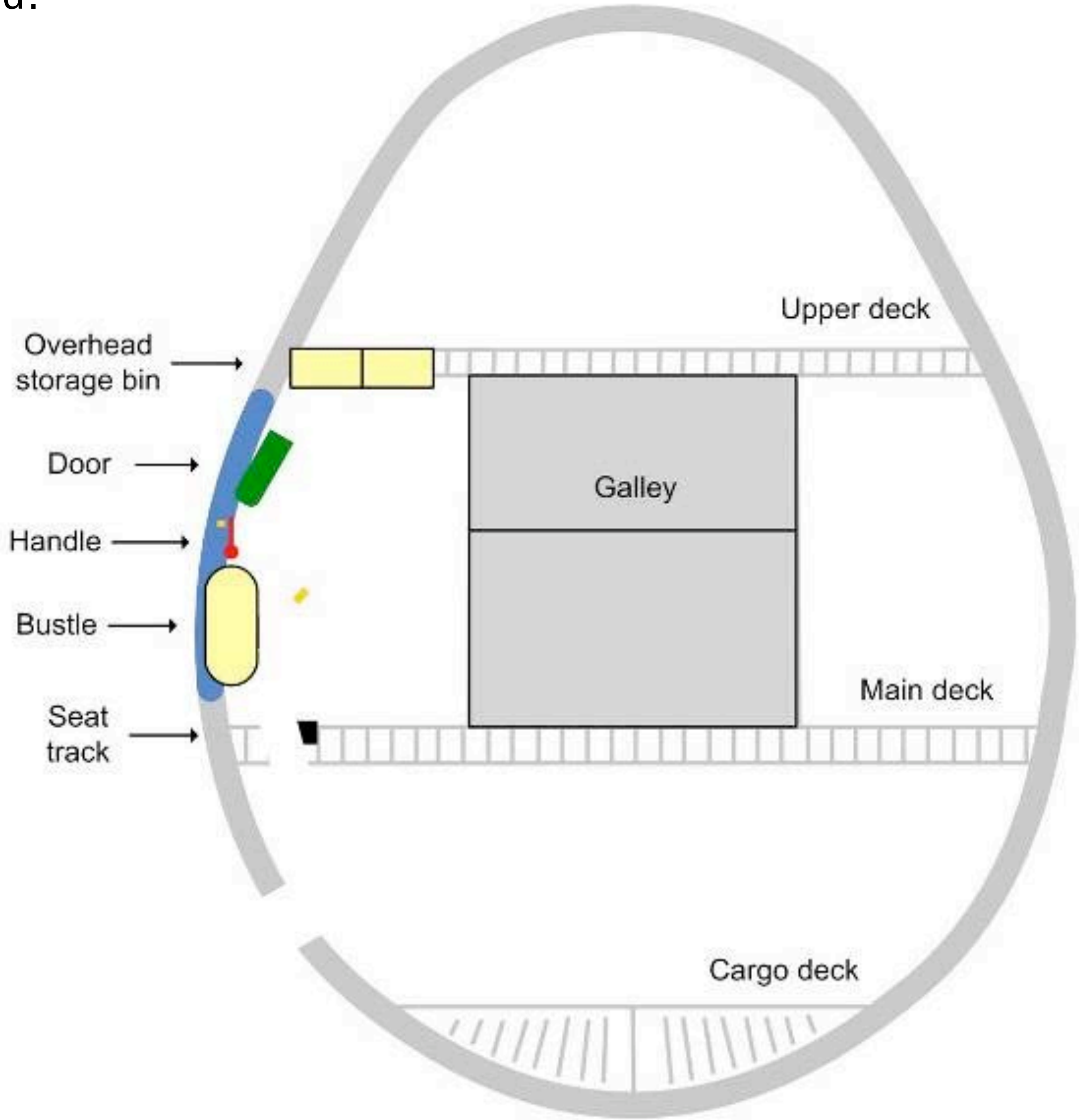


3. Cylinder impacts R2 door frame and internal door handle.

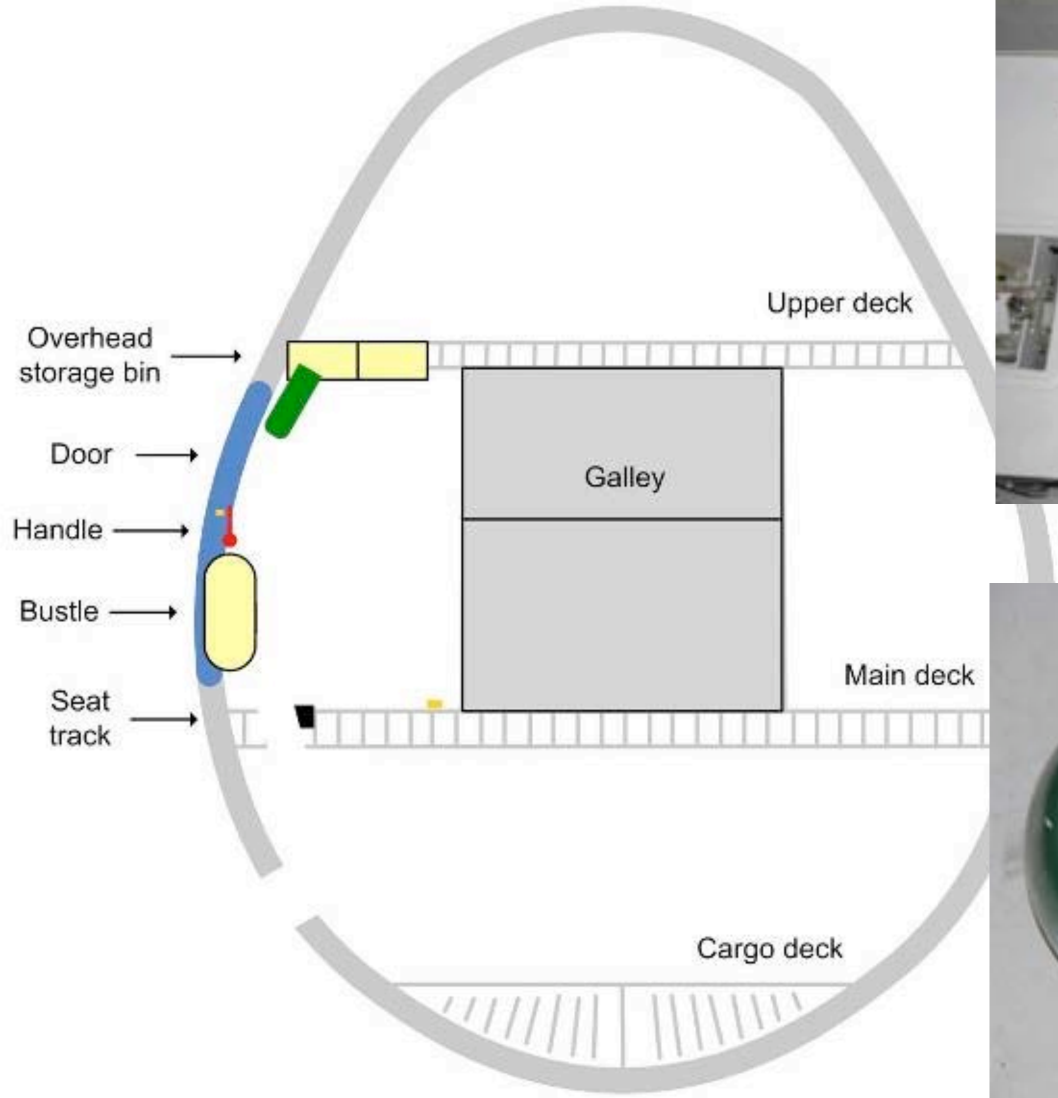


Released under Section 25 of the *Transport Safety Investigation Act 2003* as part of ATSB Preliminary Report AO-2008-053

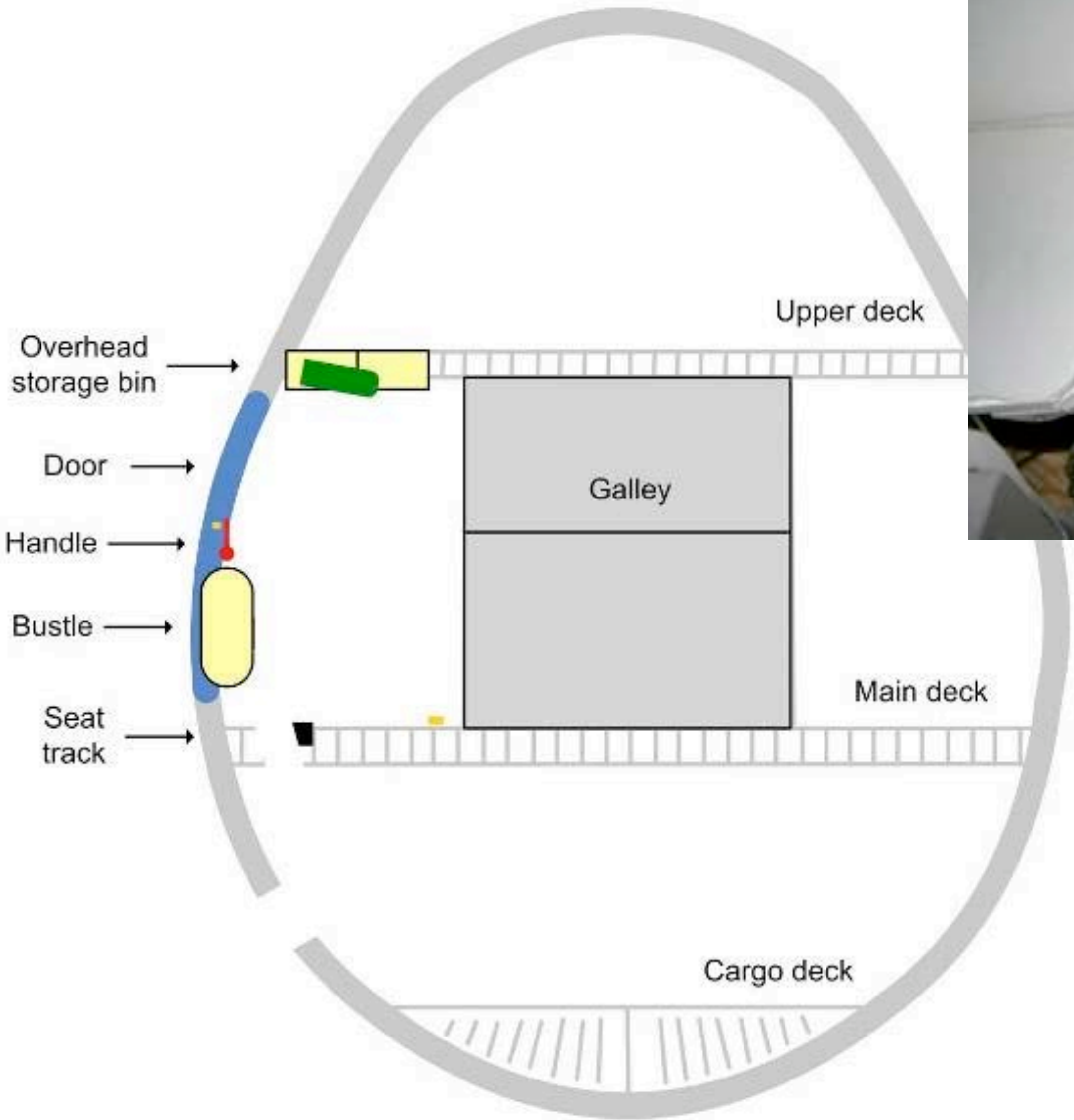
4. Door frame impact breaks off cylinder valve and causes cylinder to invert while continuing to travel upward.



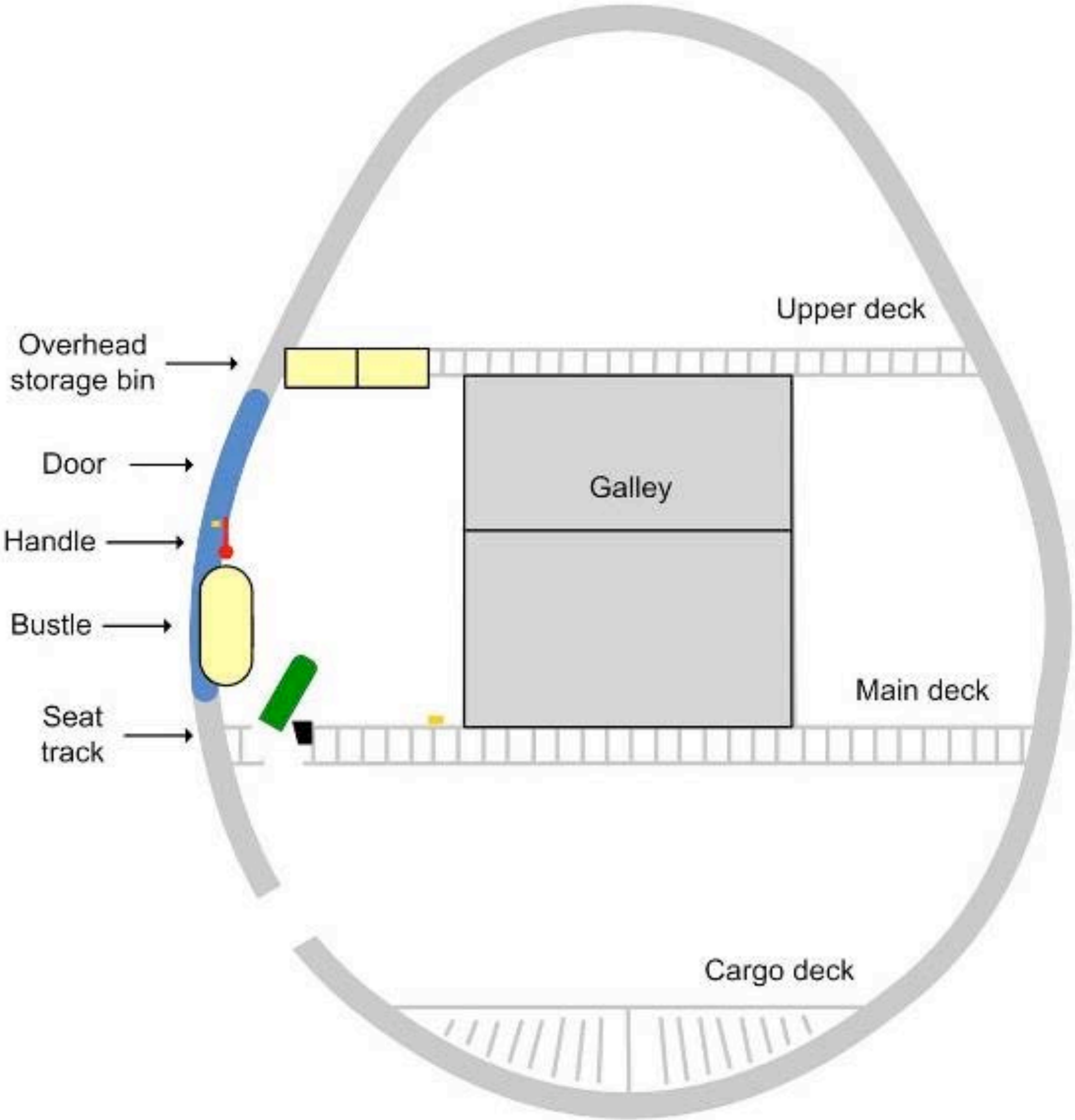
5. Cylinder impacts overhead panelling end-on, producing circular cut-out type damage.



6. Still rotating cylinder impacts overhead storage bin, producing semi-circular crushing damage.



7. Cylinder falls to cabin floor and exits the aircraft through the ruptured fuselage .

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Australian Government

Australian Transport Safety Bureau

Safe Transport