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Aircraft Depressurisation

Cabin crew information bulletin

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Aircraft depressurisation events are rare, but they can occur with little or no warning. The faster you put your oxygen mask on, the better the chance that you will stay safe and remain capable of helping others. This information bulletin is designed to supplement your airline's cabin crew emergency procedures manual and should enhance your knowledge about what can occur during an aircraft depressurisation.

Contents

WHY ARE AIRCRAFT PRESSURISED?

Modern aircraft are designed to fly at high altitudes. For example, a Boeing 747 aircraft normally cruises at an altitude of 28,000 – 35,000 ft. This is because aircraft consume less fuel and fly in relatively smooth air, avoiding bad weather and turbulence. However, the human body is not designed to survive at such high altitudes so the air pressure inside the cabin must be controlled.

The air pressure inside the cabin cannot usually be kept the same as the ambient air pressure at ground level as doing so would put excessive stress on the aircraft fuselage. Therefore, the cabin air pressure altitude (as measured by the equivalent outside altitude) gradually rises from takeoff to a maximum of 8,000 ft during the cruise. During the descent to the destination airport, the cabin pressure altitude is gradually reduced to match the ambient air pressure of the airport. Without a fully functional pressurised cabin, passengers and crew need to use oxygen systems at the altitudes typically attained during cruise.

Figure 1: Passenger oxygen marks

WHAT IS DEPRESSURISATION?

Depressurisation, also called decompression, is the reduction of atmospheric pressure inside a contained space such as the cabin of a pressurised aircraft.

Boeing 737 loss of pressurisation

On 9 November 2005, a Boeing 737 aircraft operating from Sydney to Melbourne was cruising at 40,000 ft. After feeling an upset in the stomach and discomfort in the ears, the captain noticed that the cockpit instruments indicated the cabin was quickly depressurising.

The captain commenced an emergency descent to 10,000 ft where supplemental oxygen would not be required for breathing. He attempted to inform the cabin crew of the emergency descent, but the announcement was not heard on the passenger address system in the cabin. Oxygen masks in the cabin fell from the overhead panels but not all passengers used them.

After descending for 11 minutes, the aircraft levelled off at 10,000 ft and the flight continued to Melbourne. There were no reported injuries to passengers or crew.

(ATSB Investigation Report 200505683)

CAUSES AND EFFECTS

Types of depressurisation

Three types of depressurisation are generally distinguished from each other (Mohler, 2000; Reinhart, 1996).

- An *explosive depressurisation* occurs in less than half a second. This usually only occurs in small aircraft flying at very high altitudes.
- A *rapid depressurisation* is more common and is usually associated with larger aircraft. Depressurisation occurs in a matter of seconds at a rate greater than 7,000 ft/min, and is normally associated with a 'bang' and a sudden fogging of the cabin air.
- A *gradual or subtle depressurisation* occurs over a longer time and due to the gradual change in air pressure. It can be difficult to recognise before oxygen masks fall from the cabin ceiling.

In addition to losing cabin air pressure, there have been cases of aircraft failing to pressurise after takeoff. If this is not detected and corrected by the flight crew before the aircraft reaches cruising altitude, the lack of pressurisation can also be difficult to recognise.

Depressurisation occurrences

The chances of a depressurisation problem occurring are very low, but it does happen. In the last 10 years[1], the ATSB has recorded 310 occurrences (including 124 from high capacity passenger aircraft[2]) where an aircraft pressurisation problem was cited. Although the depressurisations often occurred quickly, only two of these occurrences included evidence of a *rapid depressurisation* (a rate greater than 7,000 ft/min).

Causes of depressurisations ranged from leaking door seals and incorrect system mode selection by flight crew to mechanical-related problems.

In the majority of cases, the flight crew took some form of action such as descending the aircraft to a lower altitude, actioning the appropriate checklists, or diverting the aircraft to a nearby aerodrome. The deployment of oxygen masks was clearly identifiable in 57 of the 310 occurrences.

What causes depressurisation?

Failure of the pressure control system

The most common cause of pressurisation system failures is the malfunction of the relevant control system. This can be caused by the failure of the outflow valves that maintain cabin altitude at the desirable level.

Reduced cabin air inflow

Depressurisation events can be attributed to air inflow failure. Typical inhibitors of fresh cabin air inflow include unserviceable components in the air-conditioning system or the malfunction of an engine or compressor.

Structural failure

Aircraft structural failures that can lead to depressurisation include the impaired sealing of a door or window, cracked windows, improperly closed doors, loss of a complete door or window, or a gross structural failure of the cabin wall. A recent example of a fuselage rupture was a Boeing 747 in July 2008. Most structural failures have been caused by door or window problems.

Boeing 747-400 depressurisation

On 25 July 2008, a Boeing 747-400 aircraft with 365 persons on board departed Hong Kong on a scheduled flight to Melbourne.

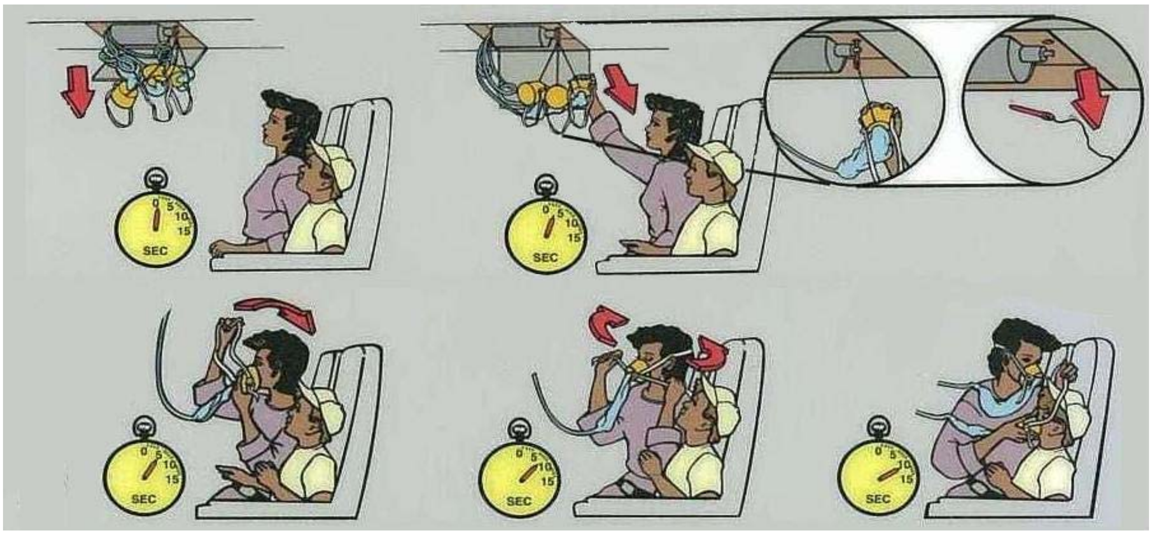
Approximately 55 minutes into the flight, while the aircraft was cruising at 29,000 ft, a loud bang was heard by passengers and crew. This was followed by the rapid depressurisation of the cabin, during which time oxygen masks dropped from the overhead compartments. The flight crew commenced a descent to 10,000 ft and diverted the aircraft to Manila. The aircraft landed safely.

(ATSB Preliminary Investigation Report AO-2008-053)

1 September 1998 to August 2008.

2 High capacity aircraft have more than 38 passenger seats.

Figure 2: An example of a passenger safety card showing how to use oxygen masks



WHAT SHOULD YOU DO?

It is imperative that you understand what to do and how to use the emergency equipment if a depressurisation happens.

1. Put the nearest oxygen mask on immediately

Oxygen is the only treatment for hypoxia (see page 5) and is critical for your survival. For example, in the case of rapid depressurisation at 35,000 ft, you may have much less than one minute to put your oxygen mask on before you begin to lose consciousness.

Don't try to go to your assigned crew position or seat if you are not close by. Use the closest available oxygen mask.

Stay calm and breathe normally if you can. Hyperventilation and physical activity is not helpful, as more oxygen is required for the body to function.

If you feel worse immediately after putting your oxygen mask on, *do not take it off.* This condition is called the 'oxygen paradox', and is simply the body's reaction to a sudden intake of oxygen after being exposed to hypoxia. You will only feel unwell for less than one minute (Harding, 1999).

2. Secure yourself as best you can

Once you are breathing through an oxygen mask, secure yourself the best you can. Cabin crew must look after their own safety by remaining secured. This may be in a spare passenger seat or wedged between two passengers. If a crew member puts their own safety at risk and is injured, there will be one less trained safety professional who can assist if the emergency escalates.

3. Help others only after you have put your oxygen mask on

You may not have time to assist others near you and then put on your mask before you become unconscious, so *put your mask on before* you instruct or help others with their masks. Normally, people recover from symptoms of hypoxia rapidly and completely after breathing sufficient oxygen.

4. Depressurisation follow-up duties

The flight crew will inform you when it is safe to begin follow-up duties. These typically include moving through the cabin to identify and help passengers and other crew who may be injured or need assistance.

Walking through the cabin will result in your body requiring more oxygen than what is required by passengers who are still seated. For this reason, cabin crew will need to use portable oxygen when moving through the cabin, even though passengers may no longer need to use their oxygen mask. It is important that passengers remain in their seats with their seatbelts fastened unless advised differently by the flight crew.

Using the supplemental oxygen

An individual oxygen dispensing unit is required for every passenger and crew member on pressurised aircraft.[3] To account for infants, there will generally be more oxygen units than there are passenger seats. Apart from above passenger seats, oxygen masks will also deploy in the toilets, crew rest, cabin crew seating positions, and in some galleys.

Figure 3: Pull down mask to start the flow of oxygen

Do not be alarmed if the reservoir bag does not inflate. When oxygen is flowing through the mask, the reservoir bag may or may not inflate depending on the cabin altitude and your breathing. The flow of oxygen to the mask is in a slow continuous stream, so you will not feel the oxygen blow out to your face.

It can be difficult to feel that oxygen is flowing. However, if you can breathe, then it is flowing. In addition, most masks have a flow indicator, such as a small green 'balloon' integrated into the reservoir bag or in the tubing.

Oxygen is either supplied through individual chemical generators for each group of masks, or through a common gaseous oxygen supply from oxygen bottles. Chemical generators can produce a smoke-like smell from the reaction. This is normal, but the smell may concern some passengers.

Will you have enough oxygen?

All Australian-registered aircraft flying above 10,000 ft are required to have provision for supplemental oxygen.[4] Enough supplemental oxygen is carried so that the aircraft can descend to 10,000 ft with everyone having enough oxygen. However, only a limited supply can be carried on an aircraft, so supplemental oxygen cannot be used indefinitely.

WHAT WILL HAPPEN?

Explosive and rapid depressurisations are easily identified as they are accompanied by a loud 'bang', flying debris (such as paper and dust), sudden fogging of the air, and dropping temperature. However, most depressurisation events are gradual and are harder to detect due to the slow increase in cabin altitude.

Commercial aircraft are required to provide warnings to the flight crew if the cabin altitude climbs above 8,000 ft.[5] The flight crew will receive a cockpit warning when the cabin altitude reaches 10,000 ft. The passenger oxygen masks should automatically deploy before the cabin altitude reaches 15,000 ft. Some aircraft also have an automated announcement telling passengers to put on the oxygen masks when they drop.

In some aircraft, an emergency pressurisation system is also fitted that automatically routes hot, high pressure, high velocity engine bleed air directly into the cabin to regulate the pressure.

What is the flight crew's response to a depressurisation event?

When flight crew notice that the aircraft is experiencing a pressurisation problem or a depressurisation, they will conduct a series of emergency procedures.

Procedures for flight crew involve firstly donning their own oxygen masks and then working through a checklist. The flight crew are unlikely to have time to make an announcement to the cabin. If necessary, the flight crew will immediately commence a descent to 10,000 ft or to the lowest safe altitude that terrain permits. The aircraft's supplemental oxygen supply is finite, so any delay in commencing the descent to a safe breathing altitude may increase the risk of injury to crew and passengers. A rapid descent also minimises the time passengers and crew are exposed to cold temperatures and minimises the risk of decompression sickness (see page 7).

3 Civil Aviation Order (CAO) 108.26.

4 Civil Aviation Order (CAO) 20.4.

5 Civil Aviation Regulation (CAR) Part 25.

The flight crew will also broadcast a 'MAYDAY' or 'PAN PAN' (the international call for urgent assistance) message to declare an emergency descent after their oxygen masks are secured. This will make air traffic control and other aircraft in the area aware of the situation, including the need for an emergency descent to a lower altitude.

After descending to a lower altitude, the flight crew will decide whether it is safe to continue the flight to the planned destination or if a diversion to the nearest suitable airport is required. This decision depends on the circumstances of the depressurisation, the condition of the aircraft, and the health and safety of passengers and crew members.

Once the aircraft is at a safe altitude, the flight crew will advise when it is safe for passengers to remove their mask. They will also inform cabin crew when they can begin their follow-up duties.

WHAT CAN HAPPEN TO YOU?

Loss of cabin pressure in a pressurised aircraft exposes passengers and crew to a high altitude environment with an extremely low temperature and lower atmospheric pressure with less oxygen.

The most common problems associated with being directly exposed to the atmosphere at high altitudes are hypoxia, pain from trapped gas in the body, cold-related injuries, and decompression sickness.

Hypoxia and loss of consciousness

The most serious hazard when exposed to high altitudes is hypoxia. Hypoxia is caused by less oxygen being available and the reduced ability of our body to use the oxygen that is available. The major symptoms and signs of hypoxia include:

- light headedness or dizziness
- blurred or tunnel vision
- headache or nausea
- diminished hearing
- tingling or numbness of finger tips.

The effects of hypoxia become more significant when exposed to an altitude above 10,000 ft. However, it can be difficult to notice many of these symptoms because you may, at the same time, be experiencing loss of judgement and self-awareness, having difficulties concentrating, and impaired memory. If oxygen is not administered, unconsciousness will follow.

Payne Stewart's last round

In October 1999, US golfer Payne Stewart's aircraft crashed when its fuel supply had been exhausted. The aircraft, a light corporate jet, was destroyed and all six occupants on board, including Stewart, were killed. It is believed that the accident may have been related to depressurisation, and the pilots and passengers may have been incapacitated by hypoxia.

Time of useful consciousness (also known as effective performance time) is the amount of time crew and passengers can continue to conduct duties and activities in an environment with inadequate oxygen. It is measured from the time when the occupants of the aircraft are exposed to a low-pressure environment to the time when the occupants have lost the capability to take corrective and protective actions, such as self-administer oxygen.

The time of useful consciousness is dependant on the pressure altitude inside the cabin following the depressurisation (Table 1). This can be considerably lower than the aircraft's altitude before the aircraft has fully depressurised.

Table 1: Time of useful consciousness (TUC)

16B6B15B14B19B13B5B12B4B11B10B3B18B9B8 bin Pressure Altitude (ft)
15,000
18,000
22,000
25,000
28,000

30,000	1 – 2 min
35,000	30 sec – 1 min
40,000	15 – 20 sec

Source: Reinhart, 1996

The actual time of useful consciousness will be shorter with faster rates of aircraft depressurisation or if you are exercising (such as running to your seat). Hypoxia symptoms can also be worse and time of useful consciousness shorter for people with respiratory or heart conditions, who are smokers or are unfit, or have been drinking alcohol.

Physiological altitude

If a passenger is a smoker or is physically out of shape, they will be at greater risk of altitude injuries than a physically fit person.

Smoking three cigarettes in rapid succession, or smoking 20-30 cigarettes in a 24-hour period prior to flying can translate into a physiological altitude of an additional 3,000 to 5,000 ft.

Source: Reinhart, 1996

Trapped gas

Air travellers may experience discomfort and pain in their middle ear, sinuses, teeth, or stomach when the aircraft is climbing or descending. This is because our bodies contain gas in these cavities, and the gas is influenced by the changes in the pressure outside the body (i.e. the cabin air pressure).

It is more difficult for gas to 'equalise' in the middle ear cavity when the cabin pressure altitude is descending than when it is climbing. In addition, a person's level of discomfort depends on the rate at which the cabin altitude changes. When the aircraft is climbing or descending, the cabin pressure altitude is generally increased or decreased at a rate of no more than about 300-500 ft/min to minimise passenger discomfort (MacMillan, 1999). However, during an explosive or rapid depressurisation, the cabin pressure altitude can climb at a considerably higher rate (see box in the next column) and can result in pain. A rapid aircraft descent following a depressurisation can also lead to pain, sometimes worse than the pain associated with the actual depressurisation. This is because it is more difficult for the inner ear to equalise when the altitude of the cabin is decreasing (such as from a rapid aircraft descent) than climbing (such as from a depressurisation). The pain experienced can be worse if passengers have ear and nose infections. In severe cases, the eardrum can rupture, causing bleeding or leaking of fluid from the ear.

In a similar way to ear pain, air pressure in the sinuses equalises with the ambient air pressure in the cabin through small openings that connect the sinuses to the nose. If you fly with an upper respiratory infection or hay fever, the gas inside the sinuses may not escape to equalise the pressure. As a result, you may experience pain in the cheeks, forehead or sinuses when the cabin pressure altitude is descending.

As gas inside your teeth and the gastrointestinal tract expands at high altitudes, a rapid depressurisation can result in discomfort, bloating and pain. Pain from trapped gas becomes more significant if you are suddenly exposed to cabin altitudes above 25,000 ft.

Boeing 747-400 depressurisation

The rapid depressurisation on the Boeing 747-400 aircraft on 25 July 2008 occurred when the aircraft was cruising at 29,000 ft and the pressure inside the cabin was equivalent to an altitude of 3,700 ft.

Following the depressurisation, the cabin pressure altitude increased to a maximum of 25,900 ft in 41 seconds, increasing by about 60,000 ft/min in the first 20 seconds.

About 20 seconds after the event, the aircraft began to descend to 10,000 ft over about 5 and a half minutes. During this time, the cabin altitude slowly reduced from 25,900 ft to 8,000 ft.

(ATSB Preliminary Investigation Report AO-2008-053)

Decompression sickness and cold injuries

Decompression sickness is caused by the development of nitrogen bubbles in the body as a result of reduced atmospheric pressure. However, it occurs at a much lower rate in aviation than in SCUBA diving. There have been no cases recorded of decompression sickness when exposed to altitudes less than 18,000 ft (without recent SCUBA diving or hyperbaric exposure).

Decompression sickness normally only occurs following long exposures (more than half an hour) to altitudes above 25,000 ft. The most common symptom of decompression sickness is 'the bends', manifested by pain in and around the large joints of the body (Heimbach & Sheffield, 1996).

> ***Safety tip: diving and flying***
>
> Don't fly until at least 48 hours after SCUBA diving involving deep dives or dives with decompression stops, to give your body enough time to rid itself of excess nitrogen.

In the event of a depressurisation, some crew and passengers may be exposed to extremely cold temperatures (down to -56ºC at higher altitudes). Exposure to these temperatures can result in injuries such as hypothermia and frostbite.

Since the flight crew usually initiate an emergency descent when the cabin loses pressure, the risk of decompression sickness and cold-related injuries is very low.

WHAT IS THE INJURY RISK?

The chances of being injured in a depressurisation event are low. In a review of all Australian pressurisation failure related occurrences over a 30 year period[6], Newman (2006) found only ten events that involved hypoxia, injury or death.

Only one occurrence resulted in fatal injuries (see 'Ghost Flight' box in next column). Of the four events in which hypoxia symptoms were reported, one involved the pilot losing consciousness, while the other cases involved occupants reporting mild symptoms of hypoxia.

> ***Ghost flight***
>
> On 4 September 2000, a Beech Super King Air 200 aircraft, operating as a charter with one pilot and seven passengers, departed Perth for Leonora, Western Australia. Five hours later, the aircraft impacted the ground in remote Queensland. The aircraft was destroyed on impact, with all persons on board fatally injured.
>
> The investigation concluded that the pilot and passengers were most likely incapacitated as a result of hypoxia due to the aircraft not being pressurised and the occupants not receiving supplemental oxygen.
>
> (ATSB Investigation Report 200003771)

There were four occurrences in which passengers sustained minor ear problems, but no reported cases of decompression sickness or cold-related injuries.

> ***Cracked windscreen***
>
> On 2 December 2005, a Boeing 737 cockpit window cracked while cruising at 37,000 ft. The subsequent flight crew actions resulted in rapid changes in cabin pressure. Eleven of the 99 passengers sustained minor ear and/or nose injuries.
>
> (ATSB Investigation Report 200506298)

Need more information?

The ATSB publishes a range of investigation and research reports that can provide you with more information on depressurisations and other important safety topics. These are available online at www.atsb.gov.au.

You can also find more flight safety information from aviation regulators:

Civil Aviation Safety Authority (CASA)
http://www.casa.gov.au/airsafe/index.htm

US Federal Aviation Administration (FAA)
http://www.faa.gov/passengers/

6 Occurrences reviewed for January 1975 to March 2006.

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