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A Sudden High-altitude Cabin Decompression Immediately Threatens Safety of Aircraft Crew and Passengers

Studies show that a quickly accomplished emergency descent is the most effective measure to prevent long-term hypoxic effects following a sudden high-altitude decompression.

Stanley R. Mohler, M.D.
Wright State University School of Medicine
Dayton, Ohio, U.S.

At cruising altitude for modern airliners, the aircraft cabin must be pressurized to approximate normal atmospheric conditions for passengers and crew. Accidental decompression during flight creates an emergency because unconsciousness and death can occur if near-normal pressurization and oxygen intake are not quickly restored.

Studies of in-flight decompressions and laboratory research have provided considerable knowledge about human decompression tolerance and about emergency measures that must be taken when there is a serious cabin-pressure loss.

Studies of on-board oxygen for use when passengers are exposed to higher altitudes began when Dr. Paul Bert conducted altitude chamber experiments in France in the 1870s.[1] His research focused on determining oxygen requirements for balloonists ascending to 15,000 feet (4,572 meters) and higher.

During World War I, pilots of German dirigibles and heavier-than-air aircraft used on-board liquid oxygen for high-altitude operations, an approach that required a method to convert the liquid oxygen to gaseous oxygen for breathing. Gaseous oxygen was initially delivered through a small tube ("pipe stem") held in the mouth, a method that was first used by balloonists in the 19th century.[2] But demand for oxygen-flow volume during inhalation was too high for a pipe stem to handle. As a result, the oral/nasal face mask was developed, with an attached reservoir bag for holding oxygen that can be rapidly inhaled in sufficient quantity.

Military personnel in the 1920s began to experiment with more effective oxygen-delivery equipment for aircrew members, and unpressurized passenger aircraft that exceeded the 14,000-foot (4,267-meter) level were provided with on-board supplemental oxygen for use at these higher altitudes.

With the introduction of jet airliners, the emergency drop-out oxygen mask developed by the U.S. Civil Aeronautics Administration's (CAA) Medical Research Laboratory (forerunner of the present Civil Aeromedical Institute) was incorporated into jet aircraft for passenger use during decompressions.[3]

If decompression is accompanied by a loud noise, it is referred to as "explosive." The U.S. National Transportation Safety Board (NTSB) has defined explosive decompression as "a violent expansion and noise from cabin air released under pressure."[4] Decompressions approximating a pressure loss of 7,000 feet (2,134 meters) per minute or more are generally considered to be in the realm of "rapid decompressions,"[4–7] although a loud noise or "bang" also defines them as explosive.

Several airline rapid decompressions have been extensively studied. Table 1 lists four examples of airliner decompressions. NTSB investigators found no evidence of postevent hypoxic (oxygen-depletion) residual injury in the passengers. The fatalities resulting from the explosive decompressions listed in Table 1 were attributed to accelerative forces on occupants ejected during the decompressions or on impact with the ground.

Those accidents and other operational experiences with airline decompressions, along with published altitude chamber decompression studies, reveal that human tolerance to rapid decompression approximates the limits shown in Figure 1 (page 3), assuming an emergency descent accomplished immediately after the decompression.

Operational experience and laboratory research have demonstrated that if the cabin altitude exceeds about 25,000 feet (7,620 meters) but remains below 35,000 feet (10,668 meters) for no longer than three minutes, humans can tolerate hypoxia if recompression occurs expeditiously to the 15,000-foot (4,572-meter) level or lower. Recovery from hypoxia by passively sitting passengers during decompression can be expected with no demonstrable brain damage if the cabin altitude remains below 25,000 feet, or is "permitted to exceed that level (25,000 feet) for only a minute or two before descending below this altitude."[8]

A series of altitude chamber decompressions, ranging from the 8,000-foot (2,438-meter) level to about the 45,000-foot (13,716-meter) level, was undergone by four test pilots and four nonpilots who were biomedically monitored. In each case, recompression to the 15,000-foot level was accomplished in approximately two minutes. The nonpilots represented passengers and had available oxygen masks typical of those available for emergency use in aircraft cabins; the pilots had available oxygen masks of a type used by flight crews.

At about the 30,000-foot (9,144-meter) level and higher, the passenger masks' oxygen flow was insufficient to prevent

Table 1
Examples of Commercial Airliner Decompression Accidents in the United States

Date	Site	Airline	Aircraft	Flight Altitude	Maximum Cabin Altitude	Total Crew and Passengers	Fatalities	Action Taken
2/24/89	Honolulu, Hawaii	United	B-747	FL 220–230	22–23,000 feet (6,706–7,010 meter)	355	9*	Immediate emergency descent
4/28/88	Maui, Hawaii	Aloha	B-737	FL 240	24,000 feet (7,315 meter)	95	1*	Immediate emergency descent
9/17/79	Boston, Massachusetts	Air Canada	DC-9	FL 250	25,000 feet (7,620 meter)	45	0	Immediate emergency descent
11/3/73	Albuquerque, New Mexico	National	DC-10	FL 390	35,000 feet (10,668 meter)	128	1*	Immediate emergency descent (Passenger masks only presented in midsection of cabin.)

* Ejected during decompression while in flight.
FL – Flight Level

Source: Stanley R. Mohler, M.D.

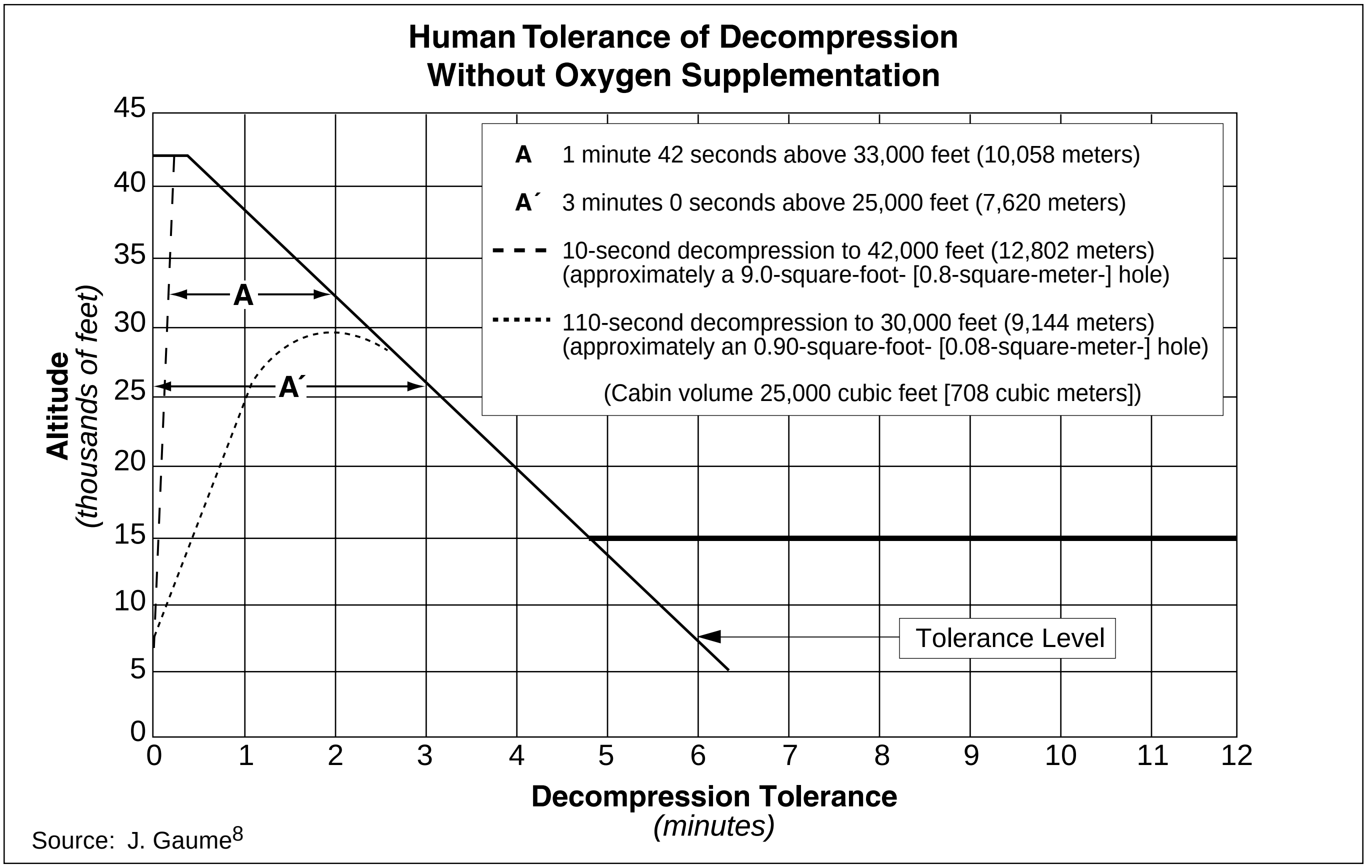

Figure 1

hypoxia. The pilot masks were effective, but it was found that any delay in donning the masks made the act impossible, because hypoxia quickly led to unconsciousness.[9]

For passengers or crew members to avoid hypoxia under these circumstances, oxygen from the masks must be available within five to seven seconds after exposure to a decompression level of 45,000 feet. Although 45,000 feet is above the cruising altitude of today's subsonic jetliners, the second-generation supersonic transports now being planned may expose larger numbers of passengers to accidental decompression at 45,000 feet or higher.

An assessment of passenger operational decompression experience and the results of altitude chamber studies concluded that attaining a cabin decompression level at or below 25,000 feet is desirable in the absence of effective passenger oxygen equipment.[8]

If the time above 25,000 feet is limited to three minutes and the time above 33,000 feet (10,058 meters) is limited to two minutes, "safe unconsciousness" would be the result if recompression to 5,000 feet (1,524 meters) occurred.[8]

Persons undergoing hypoxia under such circumstances would, in the absence of supplemental oxygen, have an experience similar to that of general anesthesia. The individual would be unconscious during the deeper hypoxic phase, and resume consciousness but, following recompression (reoxygenation), would not recall the deeply hypoxic experience. It was found that if the cabin decompression altitude does not exceed 45,000 feet, an expeditious (approximately two minutes) return to a cabin altitude 15,000 feet should not produce brain damage.[9] Cockpit crew members, who must perform with a high degree of alertness, require oxygen equipment that can be put on quickly. Flight attendants also need portable oxygen equipment so that they can continue necessary duties in the cabin during the emergency.

More than 30 years of operational experience with jet airliner decompressions, together with many more years of altitude chamber studies, demonstrate that the primary reoxygenation measure for airline passengers is a quickly accomplished emergency descent. The passenger's hypoxia tolerance (without supplemental oxygen) ranges around three minutes above 25,000 feet and around one minute, 42 seconds above 33,000 feet. An expeditious emergency descent under such conditions should be to 15,000 feet or lower. Recovery from hypoxia under the above circumstances can be expected with no damage to the brain. ♦

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Additional FSF Reading

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About the Author

Stanley R. Mohler, M.D., is a professor and vice chairman at Wright State University School of Medicine in Dayton, Ohio, U.S. He is director of aerospace medicine at the university.

Mohler, an airline transport pilot and certified flight instructor, was director of the U.S. Federal Aviation Agency's Civil Aviation Medicine Research Institute (now the Civil Aeromedical Institute) for five years and chief of the Aeromedical Applications Division for 13 years.

He has written several books on pilot medications and a book about aviator Wiley Post.

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