FLIGHT SAFETY FOUNDATION
HUMAN FACTORS & AVIATION MEDICINE
Vol. 39 No. 6 *For Everyone Concerned with the Safety of Flight* November/December 1992

# U.S. Studies Say Altitude Chamber Training Offers Important Hypoxia Recognition Training at Low Risk

***A U.S. Federal Aviation Administration (FAA) survey says current regulations should be changed to mandate that all flight crews operating above 10,000 feet should receive comprehensive altitude physiology training, including exposure to altitude chamber flights. A related FAA study says that while altitude chamber training is relatively safe, more than 1,000 physical reactions were reported during the period studied.***

*Editorial Staff Report*

*Editor's Note: An article on the potential risks of altitude chamber training in the September/October 1992 issue of* Human Factors & Aviation Medicine *has fueled debate on the necessity and benefits of such training. The previous article, citing an array of medical evidence, argued that altitude chamber training was largely unnecessary and could be replaced by less hazardous training with equal benefit to the pilot. The following report examines several recent studies that hold the opposite view. The studies conclude that such training generally involves only minor health risks and should be required for a broader spectrum of the aviation community.*

There is an increasing need for comprehensive high-altitude physiology training as the number of civilian pilots exposed to high altitude and decompression situations grows, a study sponsored by the U.S. Federal Aviation Administration (FAA) says.

"Many civilian flight personnel have not had the benefit of military flight physiology training and are unaware of the physiological phenomena that can affect the safety of flight, especially their own bodies' responses to hypoxia," the FAA report said.

The recently released report, completed in late 1991, said evidence indicated a "need for further training in high-altitude physiology for all civilian flight personnel, including recreational pilots intending to fly above 10,000 feet (during the day) or 5,000 feet (at night)." Night vision is particularly affected by hypoxic reactions at altitudes above 5,000 feet.

However, the question of when to require altitude chamber training is controversial.

While proponents say such training involves minimal danger to health, opponents of some altitude chamber training scenarios insist that the benefits do not outweigh the potential risks. They contend that there are equally effective alternative training methods that do not involve exposure to high-altitude chamber demonstrations.

Frank E. Dully Jr., M.D., an aerospace medicine specialist who opposes widespread use of altitude chambers and who authored the September/October issue of *Human Factors & Aviation Medicine*, contends that many other effective training aids are available to teach hypoxia recognition.

In compiling its report, the FAA reviewed official accident and incident reports, federal regulations, military training courses and medical literature. In addition, representatives of pilot and flight attendant unions, airlines, airframe manufacturers, the U.S. military services, the National Business Aircraft Association (NBAA), the Aircraft Owners and Pilots Association (AOPA), flight schools and universities were also interviewed.

The FAA sponsored survey, *Civilian Training in High-altitude Flight Physiology*, was conducted by the U.S. Department of Transportation's Research and Special Programs Administration.

According to the survey, factors pressing the use and expansion of high-altitude physiology training include:

- New, sophisticated aircraft (including general aviation aircraft) are capable of reaching higher altitudes than ever before (the Piper Cheyenne twin turboprop, for example, can reach 41,000 feet, and late-model Learjets can attain cruising altitudes of 50,000 feet). New airline aircraft also have the capability to cruise longer at high altitudes, lengthening flight crews' exposure to the problems of high altitude.

- Aging aircraft pose concerns about increasing decompression incidents.

- There is an apparent disparity between high-altitude physiology training for cockpit crews and cabin crews. While areas of responsibility differ, the need to know is similar. During periods of high activity, for example, flight attendants tend to become hypoxic faster than cockpit crew members. Aircraft cabins and remote galley spaces lack devices to alert the cabin crew to slow depressurization or decompression. This has caused fainting incidents in some cabin crew members, the report said.

> ***"Adding an altitude chamber flight to training can be justified on the basis of individuals' abilities to recognize hypoxic symptoms and deal with them and by the added safety that would result."***

Current U.S Federal Aviation Regulations (FAR) Parts 121 and 135 mandate high-altitude physiology training only for cockpit and cabin crews operating above 25,000 feet. "Since it is known that hypoxia can have serious effects as low as 10,000 feet, we feel that the ceiling for required training should be lowered to 10,000 feet," the survey determined.

The report concluded: "Adding an altitude chamber flight to training can be justified on the basis of individuals' abilities to recognize hypoxic symptoms and deal with them and by the added safety that would result."

Evidence collected during the survey also indicated that the "six subjects required by FAR are not being taught adequately." The six subject areas mandated for crews operating above 25,000 feet are:

- Respiration;
- Hypoxia;
- Duration of consciousness without supplemental oxygen at altitude;
- Gas expansion;
- Gas bubble formation; and,
- Physical phenomena and incidents of decompression.

The FAA survey suggested that the following subjects (not all of which are altitude related) be added to training programs:

- Flying after scuba diving;
- Stress — external and self-imposed;
- Illusions in flight, especially those leading to spatial disorientation;
- Visual problems and night vision;
- Acceleration;
- Carbon monoxide poisoning;
- Other physiological issues, including self-medication, smoking, drugs and alcohol, fatigue, nutrition, physical fitness and dehydration; and,
- Hearing, noise and vibration.

The report included a search of the U.S. National Aeronautics and Space Administration's (NASA) Aviation Safety Reporting System (ASRS) records for the period between January 1983 and May 1989. It yielded 101 reports related to flight physiology. Of those, 73 reports related specifically to high-altitude physiology.

[A search conducted in November 1992 yielded 17 reports relating to hypoxic incidents, 186 reports on incidents that required the use of supplemental oxygen and 553 reports of cabin depressurization incidents during the period 1986-1992.]

"Many of these reports show a lack of understanding on the part of the flight crew of the causes and symptoms of hypoxia and other phenomena involved in flight physiology, especially high-altitude physiology," the report said.

Reports cited included decompression incidents in which the captain did not use his oxygen mask while initiating an emergency descent at 23,000 feet and a flight attendant who left his seat (and oxygen supply) to check a rear boarding door.

The ASRS reports also documented a series of incidents involving pilots whose hypoxic symptoms caused them to deviate from assigned altitudes and assigned headings, and lose contact with air traffic control (ATC). In one incident, an aircraft descended nearly 10,000 feet before the pilot regained consciousness and recovered from a dive. Another incident involved a pilot whose lingering hypoxic symptoms caused him to ignore ATC instructions and land on the wrong runway.

Statistics for the years 1982-1988, compiled by the AOPA Air Safety Foundation's Emil Buehler Center for Aviation Safety, show that hypoxia has been a factor in several fatal accidents. The statistics, based on U.S. National Transportation Safety Board (NTSB) data for aircraft under 12,500 pounds gross weight and aircraft not in scheduled service, indicated that one hypoxia-related aircraft crash occurred each year in 1982, 1983, 1985, and 1986. Three such crashes were reported in 1987. No hypoxia-related crashes were reported in 1984 or 1988. Only single-engine, piston-powered were involved in the accidents. Only one aircraft was pressurized, a Cessna P-210. A total of eight persons died in the accidents.

NTSB data for air transport category aircraft did not identify specific hypoxia events but noted that there were aircraft fires and decompression events that could have involved physiological influences on crew and passengers, according to the FAA's report on high-altitude physiology.

The FAA report suggested that FAR Parts 121 and 135 should be amended to require altitude training for all flight crews who operate aircraft above 10,000 feet, noting that the U.S. government-published *Airman's Information Manual (AIM)* encourages all pilots to use supplemental oxygen above 10,000 feet during the day and above 5,000 feet at night.

"We have a great deal of concern over the apparent discrepancy between the *AIM* recommendations and the requirement for training only those crew members serving above 25,000 feet," the report said. "While pressurized aircraft offer protection against many of the effects of altitude, the insidious onset of hypoxia due to a pressurization leak can be very difficult to detect."

***The FAA report said that studies indicated that the current regulations are "too lax" and that the maximum altitude at which pilots can fly without supplemental oxygen should be reduced to 10,000 feet or below.***

Studies also indicate that the onset of hypoxic symptoms can begin at much lower altitudes, with impairment beginning at 8,000 feet.

According to research conducted by the United Kingdom's Royal Air Force Institute of Aviation, "studies of the effects of mild hypoxia upon the performance of novel tasks conducted in the last two decades lead to the conclusion that the maximum altitude at which pilots should breathe air [without supplemental oxygen] is 8,000 feet."

[FAR Part 91 allows a pilot of an unpressurized aircraft to fly between 12,500 feet and 14,000 feet, for a period not to exceed 30 minutes, without using oxygen. The pilot must use oxygen for any flight above 14,000 feet. Parts 121 and 135 differ from this in that the 30 minutes allowed without oxygen is between 10,000 feet and 12,000 feet and that oxygen must be used above 12,000 feet.]

The FAA report said that studies indicated that the current regulations are "too lax" and that the maximum altitude at which pilots can fly without supplemental oxygen should be reduced to 10,000 feet or below.

The report said an FAA advisory circular (AC) stated that "human performance degrades very rapidly" with exposure to altitudes above 10,000 feet.

Military pilots, the FAA report said, are given extensive indoctrination and recurrent training in altitude chambers to familiarize themselves with the individual symptoms of approaching hypoxia. Few civilian pilots receive such training, although the *AIM* supports altitude chamber training for most pilots. According to the *AIM*: "Since the symptoms of hypoxia do not vary in an individual, the ability to recognize hypoxia can be greatly improved by experiencing and witnessing the effects of hypoxia during an altitude chamber 'flight.'"

[Dully argued that "not only does hypoxia depend on the precise scenario in which symptoms occur, it also varies with age, with fatigue state, with physical conditioning and with other elements that compromise the setting. In some settings, the first symptom may be unconsciousness. The user community is better served by an appreciation of the variability and possible unpredictability of hypoxia presentations rather than their constancy. This is best done in a classroom setting at ground level."]

***"Merely stating that lack of oxygen will cause a certain set of symptoms is no substitute for … observing the effects of lowered atmospheric pressure."***

The FAA report said that "since the military services require altitude chamber flights for their flying personnel and for passengers in some aircraft types, and the *AIM* recommends this training ... we think it only logical that it be required by FAR that civilian pilots have at least an initial altitude chamber flight."

Flight crew members who are not able to recognize symptoms of hypoxia and other physiological problems that could lead to incapacitation dramatically increase the risk of inflight emergencies and fatal aircraft accidents, the report said. The onset of hypoxia is insidious, with the victim often experiencing a mildly euphoric state. Judgment, medical officials say, is the first casualty of hypoxia.

"For this reason, we feel very strongly that training of civilian flight crew members, including flight attendants and general aviation pilots, in the subject of flight physiology is necessary and should be mandated by FAR," the report said. It said that the addition of altitude chamber flights to such training is also supported by a body of medical literature.

However, the FAA report said there are potential alternatives to chamber training that may be just as effective.

"The current altitude chamber runs used by the U.S. Navy for their multi-engine flight crews are low altitude (8,000 to 25,000 feet), and they are considering doing a feasibility study on the use of mixed, inert gases to produce hypoxic effects at sea level pressures. If this proves feasible, their intent is to replace most of the recurrent training altitude chamber flights with this use of gases."

"We think this could be a sensible alternative to the altitude chamber for civilian pilot training in the recognition of hypoxic symptoms, both from safety and economic perspectives," the FAA report said.

But this program also apparently has drawbacks, according to the FAA report. The report quoted a U.S. Air Force official as saying that the mixed-gases program was investigated and abandoned.

"The Air Force evaluated a proposal to use mixed gases to produce hypoxia at ground level and rejected the proposal on the basis of risk to the student, difficulty in ensuring quality control of the gas mix, lack of realistic training and negative training outcome," the report quoted the Air Force official as saying.

Richard T. Island, director of the University of North Dakota's Aviation Physiology Department at the Center for Aerospace Sciences, says the mixed-gas technique has been a "controversial topic within the aviation physiology community for the past several years."

"If the only value of chamber training was the hypoxia demonstration, gas mixtures might be a viable option to the use of an altitude chamber," Island said.

"But will aviators accept being told to don a mask and breath mixed gases? Will there be predictable negative transfer from use of a procedure that teaches aviators to don a mask to create symptoms when in reality donning a mask is the procedure we now teach as a preventative/corrective measure for hypoxia? Will there be problems controlling mixtures of gas, such as has been experienced in the scuba diving community? Will there be a negative impact of reducing the number of safety observers?

"These are all questions we must consider before accepting gas-mixtures as an alternative to altitude chambers. To date, gas-mixture hypoxia demonstrations have received little support as the optimum training technique."

Island, who is associated with civilian-operated altitude chamber training at the UND Center for Aerospace Sciences, said chamber training remains the most realistic method of demonstrating the unique effects of hypoxic (altitude-induced) hypoxia. He said UND chamber training is part of a comprehensive course that covers a range of aviation human factors issues.

Island acknowledged that chamber training can involve some risk. But he added: "We teach the effects of reduced barometric pressure in the classroom, prior to every chamber flight. Included in these lessons are recognition, prevention and management techniques for 'evolved gas problems,' more commonly known as 'the bends' or decompression sickness (DCS). There is always a chance that evolved gas problems can occur, no matter what is done to prevent them."

But Island said his statistics show that after 50 years of training, there is "still only a .118 percent chance that an evolved gas problem will occur during or shortly after exposure to altitude in an altitude chamber."

"Until empirical data is presented to show any other process which is as effective as the altitude chamber for preparing aviators to cope with the effects of reduced barometric pressure, our professional opinion is that the risks to aviators who have had no training, or inadequate training about aviation physiology topics, are far more significant than risks inherent with the use of altitude chambers," Island said.

[There are four types of hypoxia. Hypoxic hypoxia is a condition caused by reduced barometric pressure, affecting the body's ability to transfer oxygen from the lungs to the bloodstream. Chamber flights demonstrate hypoxic hypoxia.

Histotoxic hypoxia can be induced by the introduction of substances like alcohol or drugs into tissue, reducing its ability to accept oxygen from the bloodstream.

Hypemic hypoxia is a result of the blood being unable to carry oxygen, perhaps caused by exposure to carbon monoxide in the cockpit.

Stagnant hypoxia results from the body's inability to carry oxygen to the brain, which can result from a severe wound or when gravity-forces cause the blood to pool in the lower extremities.]

Joseph L. Vogel, an adjunct assistant professor at Ohio State University's Department of Aviation, said in an article commissioned by the FAA report that "merely stating that lack of oxygen will cause a certain set of symptoms ... is no substitute for actually experiencing the symptoms and observing the effects of lowered atmospheric pressure."

Vogel advocates requiring a formal course of physiological training (including flight chamber training) for all commercial and airline transport pilots, flight instructors and general aviation pilots who routinely fly at altitudes above 12,000 feet.

"The problem of whether to require physiological training for private pilots should be beyond argument," Vogel said. "What can be argued is the type of training to be required and to whom it should be applied."

A related FAA report published in 1990, *The FAA Altitude Chamber Training Flight Profile: A Survey of Altitude Reactions 1965-1989*, also concluded that altitude training "provided a safe learning environment without compromising the student's health and safety."

However, the survey noted that there were "some mild and expected reactions" and that the health of some chamber instructors has suffered "due to age and cumulative number of exposures." The survey examined FAA altitude chamber training from 1965 to 1989. All of the altitude chamber training flights were conducted at the FAA's Civil Aeromedical Institute in Oklahoma City, Oklahoma.

**Table 1**
**FAA Altitude Chamber Reactions**

| Symptom | Profile Type A (1965-1971)* 479 Flights 3,034 Students | Profile Type B (1973-1989)* 1,024 Flights 9,725 Students | Total |
|---|---|---|---|
| Aerotitis media | 248 | 634 | 882 |
| Aerosinusitis | 81 | 119 | 200 |
| Aerodontalgia | 6 | 14 | 20 |
| Hyperventilation | 3 | 12 | 15 |
| Abdominal distress | 5 | 14 | 19 |
| Claustrophobia | 2 | 0 | 2 |
| Decompression sickness | 2 | 8 | 10 |
| Apprehension | 0 | 9 | 9 |
| Tingling | 0 | 3 | 3 |
| Unconsciousness | 0 | 1 | 1 |
| | | | 1,161 |

* Data from the years 1972 and 1985 were not available.

The three reported cases of tingling occurred following pressure breathing and may have been related to hyperventilation. During a hypoxia demonstration at 22,000 ft., one student lost consciousness one minute and 54 seconds into the demonstration. He remained unconscious during the emergency descent until the chamber reached an altitude of 8,000 ft.

Source: U.S. Federal Aviation Administration

Of the 12,759 trainees involved in the program, 1,161 suffered various reactions associated with chamber training.

A total of 882 cases of aerotitis media (inability to ventilate the middle ear due to barometric pressure change) and 200 cases of aerosinusitis (sinus inflammation caused by barotrauma). There were 10 reported cases of decom-

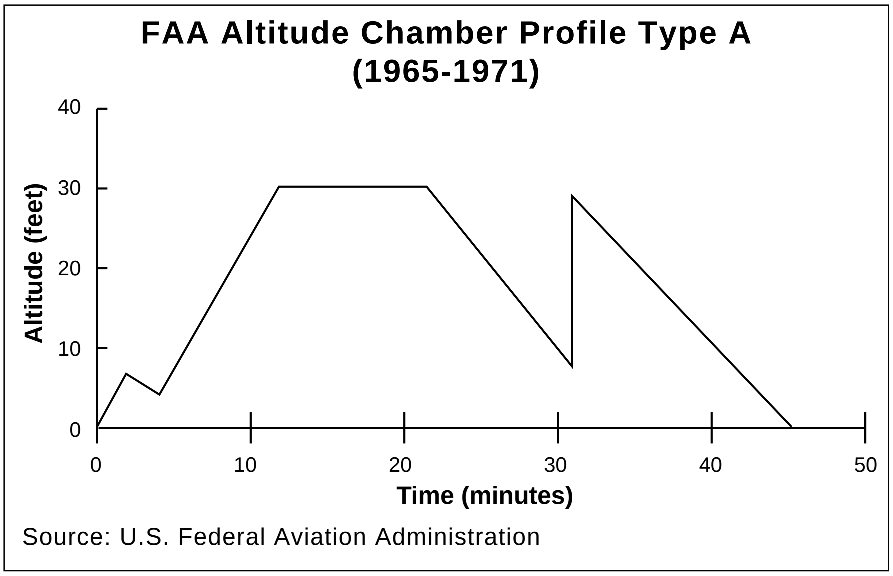


**Figure 1**

pression sickness and one loss of consciousness episode. There were also cases of trapped gas syndrome.

[Air trapped in body cavities such as the middle ear, sinuses, stomach and teeth (aerodontalgia) expands as pressure decreases with altitude, causing symptoms ranging from mild bloating to debilitating pain.]

The chamber survey described the following two procedures (Figures 1 and 2) used during the 23-year survey period of FAA altitude chamber flights:

“Four instructors are required to operate an FAA altitude chamber flight: a chamber operator, a flight recorder, and two inside observers; also, a flight surgeon must be on telephone standby. The inside observers who participated in these series of training flights are all ex-U.S. Air Force chamber technicians with many years of altitude chamber experience.”

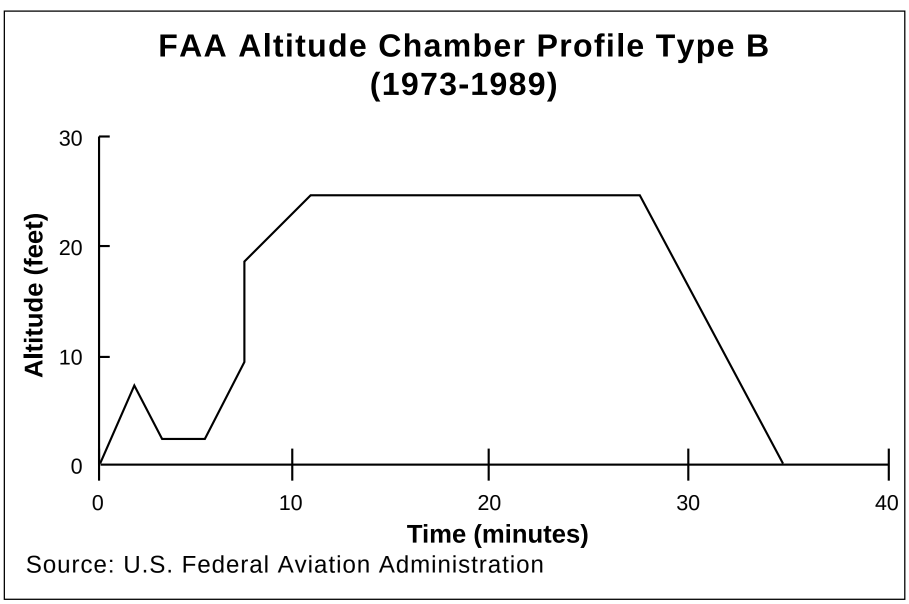


**Figure 2**

• Altitude chamber flight Profile A (1965-1971). “After a routine medical inquiry ... students take assigned seats in the altitude chamber. An evacuation to 7,000 feet at a rate of 3,000 feet per minute begins. The chamber operator levels the chamber on reaching 7,000 feet and lowers the chamber to 2,000 feet at a rate of 2,000 feet per minute. On reaching ground level, any student suspected of being a candidate for sinusitis or aerotitis media is removed from the chamber. The chamber run is then continued at a rate of 3,000 feet per minute to 29,000 feet where the students experience symptoms of hypoxia. Exposure to 29,000 feet averages about eight minutes. After the demonstration, the chamber returns to 8,000 feet at a rate of 2,000 feet per minute. The students next experience a decompression from 8,000 feet to 29,000 feet in 20-24 seconds. On arriving at 29,000 feet, the chamber descends to ground level at a rate of 2,000 feet per minute. Total time in the chamber averages about 45 minutes.”

• Altitude chamber flight Profile B (1973-1989). “Students are taken to 6,000 feet at 3,000 feet per minute. The chamber is returned to 2,000 feet at a rate of 3,000 feet per minute. Students suspected of having trapped gas problems or exhibiting unsuitable physiological symptoms are removed from the chamber. The chamber is next evacuated to 8,000 feet at a rate of 3,000 feet per minute. Quick-don oxygen masks are hanging next to each student. Decompression is initiated at 18,000 feet during a 5-second time period.

“After students don their masks, the chamber continues to 25,000 feet for the hypoxia demonstration. Students experiencing hypoxia at 25,000 feet are restricted to a maximum time of five minutes without supplemental oxygen. After the hypoxia demonstration, the chamber is returned to ground level at a rate of 3,000 feet per minute. Average flight time is 34 minutes. Denitrogenation is not a prerequisite for these flights.”

The altitude chamber survey said inside observers made up most of the 10 reported cases of decompression sickness during the period studied. Reactions reported included elbow, ankle

## Table 2
## FAA Decompression Reactions On 10 Chamber Flights (Suspected Decompression Sickness)

**Students**

| Symptom | Altitude | Results |
|---|---|---|
| 1. Elbow pain | 25,000 ft. | Relieved at 24,000 ft. |
| 2. Ankle pain | 23,000 ft. | Relieved at ground level |
| 3. Shoulder pain | 18,000 ft. | Relieved at 10,000 ft. |

**Inside Observers**

| Symptom | Altitude | Results |
|---|---|---|
| 4. Joint pain | 29,000 ft. | Relieved at 27,000 ft. |
| 5. Wrist pain | 28,000 ft. | Relieved at 22,000 ft. |
| 6. Knee pain | 25,000 ft. | Relieved on descent |
| 7. Parasthesia (foot) | 23,000 ft. | Relieved at 13,000 ft. |
| 8. Shoulder pain | 25,000 ft. | Grounded |
| 9. Neck, arm and shoulder pain (several episodes) | 25,000 ft. | Grounded |

10. One inside observer, with more than 30 years of participation in altitude chamber exposure, experienced two reported and several undocumented episodes of neck, shoulder and arm pain during a two-year period. Dull chronic pain in these areas of the body intensified with increased frequency of exposure. Elevated levels of pain would persist for two or three days following each exposure to altitude.

Source: U.S. Federal Aviation Administration

and shoulder pain among students and wrist, knee and neck pain among inside observers (Table 2).

An inside observer with more than 30 years of participation in altitude chamber flights was diagnosed as having tendonitis and bursitis with the "impression that years of repeated episodes of untreated limb bends may have contributed to the development of a painful shoulder."

Data relating to older observers raised several questions about long-term chamber exposure, the survey said. It said that future studies must determine if age contributes to a susceptibility to decompression sickness, if long-term exposures predispose an individual to orthopedic or neurological problems later in life and if frequency and duration of altitude exposure during a period of many years "adversely affects respiration and circulation, the digestive system, hearing and other body systems."

The survey concluded that while student reactions were largely "mild and expected," continued and expanded monitoring was necessary for senior inside observers.

"If future research should support the premise that age and long-term exposure to altitude have a deleterious effect on the body, then different safeguards may be needed for senior inside observers," the altitude chamber survey concluded. ♦

*Editor's Note: The following should be read after column 1, paragraph 2, page 5.* Data indicate that the rate of decompression sickness at chamber altitudes of 25,000 feet and below are only .042 percent. Island attributes the lower rate of altitude limitation of 25,000 feet and slower rates of ascent and descent used for civilian training. The .118 percent statistics include military chamber operations to 50,000 feet, according to Island.

**Articles in this publication may be reprinted in whole or in part, but credit must be given to: "Flight Safety Foundation and *Human Factors & Aviation Medicine*," as well as the author.**

**What's Your Input?**

Flight Safety Foundation welcomes articles and papers for publication. If you have an article proposal, a completed manuscript or a technical paper that may be appropriate for *Human Factors & Aviation Medicine* please contact the editor. Submitted materials are evaluated for suitability and a cash stipend is paid upon publication. Request a copy of "Editorial Guidelines for Flight Safety Foundation Writers."


**HUMAN FACTORS & AVIATION MEDICINE**





**ISSN 1057-5545**