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Civilian Training in High-Altitude Flight Physiology

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Final Report

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16. Abstract

A survey was conducted to determine if training in high-altitude physiology should be required for civilian pilots; what the current status of such training was; and, if required, what should be included in an ideal curriculum. The survey included a review of ASRS and NTSB accidents/incidents where high altitude was a contributing factor, current FARs, the Airman's Information Manual, and military training courses. In addition, representatives of pilot and flight attendant unions, airlines, airframe manufacturers, the armed services, NBAA, AOPA, flight schools, and universities were interviewed. And, an expert in the field was identified and asked to write a discussion paper for inclusion in the report.

The survey determined that there is a need for such training. It was also found that current training practices are not uniform and sometimes do not even address those subjects required by Federal Aviation Regulations.

The report contains recommendations for subjects to be included in a core curriculum and additional subjects that may be included for a more complete knowledge of high-altitude physiology issues relevant to civilian flight.

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PREFACE

This report describes a survey that was conducted to determine if training in high-altitude physiology was needed for civilian flight crews; whether current training was adequate; and what subjects would be recommended for inclusion in a core curriculum, if additional training should be required. This report describes the methods used to acquire the information for the survey and the results of the survey. Also included are recommendations for subjects for a core curriculum and additional subjects for an expanded curriculum.

This paper was prepared for the Biomedical and Behavioral Sciences Branch of the Office of Aviation Medicine of the FAA.

The report was prepared by the Operator Performance and Safety Analysis Division of the Office of Research and Analysis at the Volpe National Transportation Systems Center, and was completed under the direction of VNTSC Program Manager M. Stephen Huntley, Jr. Research for the report and its preparation were the responsibility of John W. Turner of EG&G Dynatrend.

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METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 | 25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

EXECUTIVE SUMMARY

Some National Transportation Safety Board staff members have expressed a concern that high-altitude flight physiology training for civilian flight personnel should receive greater emphasis than it currently does. Others in the aviation industry agree. Among their reasons are the following:

- New-generation aircraft are capable of reaching higher flight altitudes than before (e.g., Piper Cheyenne turboprops that reach FL410 and late-model Learjets reaching FL500). Moreover, new airline aircraft have the capability to cruise longer at high altitudes than older aircraft, lengthening flight crews' exposure to the problems of high altitude.

- Aging aircraft and greater decompression possibilities are growing concerns.

- There is an apparent disparity between the high-altitude physiology training for cockpit crews and cabin crews. While areas of responsibility differ, the need to know is similar. This becomes more obvious with the knowledge that during periods of high activity, flight attendants tend to become hypoxic faster than sedentary cockpit crewmembers.

The authors were asked to:

- Verify the need for more training in high-altitude physiology.

- Review current training practices in the industry and in academia.

- Recommend a curriculum for use in high-altitude training.

The following methods were used to gather information:

- To determine the need for training, we reviewed Aviation Safety Reporting System (ASRS) and National Transportation Safety Board (NTSB) reports and interviewed representatives of pilot and flight attendant unions.

- To identify current training practices, we surveyed airlines, airframe manufacturers, the armed services, the National Business Aircraft Association, the Aircraft Owners and Pilots Association, flight schools, and institutions of higher learning.

- To ascertain subjects to include in a curriculum, we reviewed pertinent publications and curricula.

- To provide additional information in this field, we commissioned an expert opinion paper (see Appendix A).

Based on the information gathered, we feel that there is a need for further training in high-altitude physiology for all civilian flight personnel, including recreational pilots intending to fly above 10,000 feet (day) or 5,000 feet (night). (This is because of the hypoxic effect on night vision above 5,000 feet.) Although we realize that training all those liable to fly above 5,000 feet would create very large initial training demands, we encourage it. 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. (Each person's response differs in some respect.)

Our study also leads us to believe that at present not even the six subjects required by FAR are being taught adequately. For crews operating above 25,000 feet, those required subjects are:

- Respiration.

- Hypoxia.

- Duration of consciousness without supplemental oxygen at altitude.

- Gas expansion.

- Gas bubble formation.

- Physical phenomena and incidents of decompression.

We feel that those required subjects should be addressed fully, and that the use of oxygen equipment, both fixed and walk-around, should also be taught. In addition, we recommend teaching the following subjects, not all of which are altitude related:

- Flying after diving.
- Stress, external and self-imposed, and the manner in which it affects individual performance.
- Illusions in flight, especially those leading to spatial disorientation. (The AIM says that "Illusions rank among the most common factors cited as contributing to fatal aircraft accidents.")
- Visual problems and night vision.
- Acceleration and force fields.
- Carbon monoxide poisoning in flight.
- Other physiological issues, including self-medication, smoking, use of drugs and alcohol, fatigue, nutrition, physical fitness, and dehydration.
- Hearing, noise, and vibration.

This latter group of subjects is addressed in the AIM and/or in military courses of instruction in flight physiology. We also feel that 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.

FARs 121 and 135 mandate training in flight physiology only for 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.

Another finding deals with oxygen use by pilots as mandated by FARs 91, 121, and 135. These regulations specify different altitudes at which oxygen must be used by pilots operating under the three parts. Since pilots under each of the three parts have similar needs for oxygen, and the effects of hypoxia can be as disastrous for any, we feel these regulations should reflect the same requirements for all pilots.

1. INTRODUCTION

It is a concern of some NTSB staff, as well as others in the aviation industry, that more emphasis should be placed on training in high-altitude physiology. The following would seem to support that position:

- New-generation aircraft are being routinely flown at higher altitudes, **including general aviation aircraft.**
- Concerns about aging aircraft and the possibility of decompression are growing.
- 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 crewmembers who were not alerted to the problem by seeing passenger masks deploy.
- There is a lack of in-depth cabin crew training in proper use of all supplementary oxygen devices they might encounter in normal duties. (A recent DC-10 incident, investigated by the NTSB, found flight attendants insufficiently trained to recognize oxygen flow to the masks, and resulted in their moving passengers around to find "usable masks.")
- An apparent disparity exists in training between cockpit and cabin crews in high-altitude physiology. While the responsibilities are different, the need to know is similar. The difference in activity level between busy flight attendants and a seated cockpit crew can result in hypoxic flight attendants with no recognition of the problem by the pilots. And, with a two-person cockpit crew becoming more prevalent in the industry, there will seldom be a pilot available to help the cabin crew in an emergency.

To determine whether more emphasis should be placed on high-altitude flight physiology training we needed to:

- Identify specific conditions and procedures that may contribute to problems at high altitude and evaluate the need and requirements for high-altitude physiology training for flight crews.
- Identify current methods, facilities, and curricula available for use in such training.
- Identify information that should be included in training for high-altitude physiology and identify the flight operations where such training would be particularly beneficial.

The following methods were used to gather information:

- To determine the need for training, we reviewed ASRS and NTSB reports regarding accidents/incidents where altitude was a contributing factor. We also interviewed representatives of pilot and flight attendant unions regarding problems associated with hypoxia, decompression, and other altitude-related problems.
- To identify current training practices, we surveyed airlines, airframe manufacturers, the armed services, NBAA, AOPA, flight schools, and institutions of higher learning.
- To ascertain subjects to include in a curriculum, we reviewed the Airman's Information Manual (AIM), current FARs, and military courses of training.
- To ensure that our information covered as broad a perspective as possible and included the views of researchers as well as those of practitioners, we commissioned Prof. Vogel of Ohio State University to prepare a position paper (attached as Appendix A) concerning current issues in flight physiology. Prof. Vogel is a retired Air Force fighter instructor pilot and is currently an Adjunct Assistant Professor of flight physiology at the university.

The following products were requested and are provided herein:

- An assessment of the need for training in high-altitude physiology for airline and general aviation flight crews.
- A review of current training practices in high-altitude physiology.

- Recommendations for a core curriculum for high-altitude physiology training where such training is required.

Other information was received and recommendations made on subjects pertaining to flight physiology which do not directly relate to high altitude.

2. AVIATION SAFETY REPORTING SYSTEM REPORTS

A search of ASRS full-form records (versus those with no text) for the period between January, 1983 and May, 1989, yielded 101 reports concerned with flight physiology. Seventy-three of those pertained specifically to high-altitude physiology. Of the other 33, many involved pressurization or decompression problems and some aspect of flight physiology, but took place at low altitudes, generally 5,000 feet or below. Many of these reports show a lack of understanding on the part of the flight crew of the potential dangers involved. Twelve of the 73 reports were suggestive of inadequate training and cockpit resource management (CRM). Five involved noncompliance with the Federal Aviation Regulations (FARs). Fifteen reports involved major equipment problems. However, many of the reports also had positive aspects. Forty-five reports indicated that the crews followed company-operating procedures in dealing with the emergencies, and an additional five reports indicated good crew interaction, good training, or both. Since some of the reports were typical of more than one category, the total is more than 73.

What follows provides illustrations of the five categories of reports mentioned above. As mentioned, forty-five reports illustrate good reactive training of front-end crews in the handling of decompressions, whether explosive or insidious. However, many of these reports show a lack of understanding of the causes and symptoms of hypoxia and the other phenomena involved in flight physiology, especially high-altitude physiology.

Inadequate Training or Cockpit Resource Management

38570—**Shortly after takeoff, a rear boarding door came open and the integral stairs deployed.** The flight crew experienced no control problems and returned to land. One of the flight attendants in the rear unfastened his seat belt and went to the open door to check it out, although his emergency training and common sense should have made him aware that was a life-threatening move. The flight had just begun to pressurize, so the decompression was minor, or much worse could have happened.

47398—**The aircraft depressurized at FL280.** The reporter felt a pressure change in his ears. The Captain checked the Second Officer's (S/O) panel (the S/O was in the cabin), donned his O_2 mask, actuated the speed brakes and began an emergency descent without communicating with the reporter. From the Captain's actions, the reporter assumed there was a serious problem, donned his O_2 mask, and alerted the en route Air Traffic Control (ATC) center to the emergency descent. This incident shows a total disregard by the Captain of training in emergency descent procedures that stress crew communication and CRM.

74860 — **The aircraft experienced a rapid decompression.** The crew followed emergency procedures and made a rapid descent after transmitting in the blind to the center and not receiving a reply. The crew did not squawk 7700 (emergency transponder code) during descent. The reporter felt, in retrospect, that training should include the necessity to be in contact with ATC prior to descent, or at the least, to squawk 7700 so as to alert ATC to the need to clear other traffic in the area of the descent.

35579 — **The aircraft sustained an explosive decompression due to the loss of the First Officer's (F/O) side window at FL230.** The F/O received minor injury, and 1/2 of his O_2 mask was ripped away and unusable. The Captain made an emergency descent with the F/O doing the checklists, but the Captain did not use his O_2 mask at all. This shows a lack of training in, and understanding of, the effects of unpressurized flight without oxygen, since the usual reaction to such a pressurization loss is to don the O_2 mask.

Noncompliance with FAR Requirements

36950 — **The flight continued to its destination after an emergency descent, during which passenger O2 masks were deployed.** At one point during the balance of the trip, flight was conducted at FL270. The Minimum Equipment List (MEL) for the airplane specified no flight above FL250 without the availability of automatic presentation of passenger O_2 masks. The masks could not be presented automatically because they had been deployed in the previous emergency descent. This involves noncompliance with FAR 91.30, regarding Minimum Equipment Lists, and a lack of knowledge of MEL requirements.

30855 — **The aircraft suffered a loss of pressurization at FL270.** The crew had experienced problems with the pressurization controller on three previous legs. The FAA jumpseat rider wrote crew violations for improper use of oxygen masks. FAR 121.329 (b) (1) specifies "at cabin pressure altitudes above 10,000 feet, up to and including 12,000 feet, oxygen must be provided for and used by each member of the flight crew on flight deck duty, and must be provided for other crewmembers, for that part of the flight at those altitudes that is of more than 30 minutes duration." The flight deck crew donned their O_2 masks when the cabin altitude (as opposed to aircraft altitude) went above 12,000 feet, and after 30 minutes. This is another example of noncompliance with the FARs.

67644 — **This report involves a new type of quick-donning crew O2 mask which does not perform as required by the FARs.** The harness is designed to inflate away from the mask when the mask is removed from its container, and then deflate for a snug fit after being placed on the wearer's head. Instead, most masks tested by the reporter had the harness inflate inside the mask and jam, so as to require a two-handed operation for donning. FAR 91.32 (b) (1) (ii) requires that a mask can be taken from its hanger/container, and within five seconds and with one hand, placed on the face, and be ready for use. FAR 121.333 (c) (2) has the same requirements and adds "the certificate holder shall also show that the mask can be put on without disturbing eyeglasses and without delaying the flight crewmember from proceeding with his assigned emergency duties." (It should be noted that on several occasions we have seen this type of mask demonstrated in a cockpit without the reported problem.)

Other Equipment Problems

87585 — **An aircraft climbing through FL305 experienced rapid decompression, and cabin pressure was lost in about 10 seconds.** The aircraft had been written up for previous pressurization problems but maintenance had been unable to duplicate the problem. Subsequent to this occurrence, a large crack was found in the cabin in the right wheel well area. This problem had been the subject of two previous FAA Airworthiness Directive (AD) notes. The crew made an emergency descent and ran the "EXPLOSIVE DECOMPRESSION" checklist.

48316 — **A crew at FL350 on an oceanic route experienced an uncontrollable cabin depressurization.** They descended to 10,000 feet and returned to their point of departure. Seventy-nine of the passenger O_2 masks did not deploy automatically, nor could the crew deploy them with the cockpit control switch. The passenger O_2 masks that did deploy were of the chemical generator type and left a burning odor in the aircraft which the crew could not identify. Because of this, the crew wore O_2 masks for the remainder of the flight. The crew had never been exposed to the smell of a deployed chemical generator O_2 mask and did not know what caused the burning smell. They should have recognized the smell from exposure to it in initial or recurrent training, as required by FAR 121.417 (c) (2) (i) (C).

70672 — **An aircraft suffered a decompression at the beginning of descent.** One of the flight attendants, working in an aft galley, recognized her hypoxic symptoms, discovered the passenger masks had deployed, assisted a small child in going to its m[illegible]r, then passed out from lack of oxygen. She was given supplemental oxygen by another flight attendant and was all right. However, flight attendants are usually trained to don their own masks before assisting others so they will be capable of providing such help. This flight attendant reporter also brought out important considerations concerning chemical oxygen generators. Considerable heat and smoke are caused in the generation process. Reportedly, the heat has caused burns to, and the smoke has been inhaled by, crew and passenger alike. In addition, on assuming bracing positions for an emergency landing, a problem arises with the stowage of the paraphernalia from the seat-back style of chemical generators (such as in the DC-10). These canisters are also reported as being so hot as to prevent some passengers from sitting back in their seats and extending their oxygen tubes far enough to initiate the sequence for their canister to provide oxygen flow. This last problem contravenes FAR 25.1450 (b) (1) that says "Surface temperature developed by the generator during operation may not create a hazard to the airplane or its occupants."

Crew Followed Company Operating Procedures

85640 — **An aircraft in cruise at FL310 experienced an engine explosion and rapid decom-**

pression. The exploding engine left a hole in the fuselage large enough for a man to crawl through. The crew followed emergency training procedures, made an emergency descent, fought the fire, and did all checklists according to their company procedures. The first reporter said it took about 10 seconds to don his O_2 mask and he felt confusion during the initial stages of the emergency. Since time of useful consciousness is measured in seconds, at that altitude, he might have approached that length of time and felt the effects of hypoxia. Both reporters felt they had good training to handle single emergency situations. However, they felt that the lack of compounded, multiple-emergency simulator training left them less prepared to cope with this combination of happenings than they would have liked.

36048 — **While the aircraft was climbing through FL210, the cabin altitude exceeded 10,000 feet and the cabin altitude warning horn sounded.** The crew donned their O_2 masks and attempted all recommended procedures to control the cabin altitude (e.g., selected standby; selected manual control; closed the outflow valve). They were unable to regain control, made an emergency descent, and returned to the point of departure. They made all prescribed contact with ATC and followed company operating procedures for the emergency.

33192 — **On climbout from Newark through FL240, the crew experienced rapid loss of cabin pressure.** They tried all the recommended procedures to control cabin pressure manually, then requested and made emergency descent, and followed emergency procedures.

GOOD CREW INTERACTION, GOOD TRAINING, OR BOTH

29778 — **The aircraft sustained a loss of pressurization.** The cabin altitude climbed to 20,000 feet. The crew followed all emergency procedures. *The flight attendants were cited by the reporter for* doing a good job. This report had many indications of good crew coordination and flight attendant training *in these procedures.*

96377 — **The cabin altitude began to climb, for no apparent reason, on an aircraft in cruise at FL350.** The crew attempted manual control but were unsuccessful. They began an emergency descent and were able to control the cabin altitude when the aircraft reached FL220. The descent was done smoothly enough so that passengers were unaware of it and the flight continued to its destination at the lower altitude. The following quote from the reporter indicates a high level of preparedness and professionalism: "As far as I'm concerned, this was just another day in aviation. No big deal, but felt it would be wise to inform you of the situation that did occur."

Many of the crews involved in these ASRS reports performed the required emergency procedures in the manner that they were supposed to, and removed their aircraft and passengers from immediate danger. But a thread of ignorance of important factors dealing with high-altitude physiology and the dangers involved, and the regulations regarding them runs through the reports.

A well-trained crew, conversant with emergency procedures, knowledgeable of the regulations, and familiar with the physiological dangers inherent in high-altitude pressurized flight, can handle almost any emergency without further harm to aircraft, crew, or passengers. However, the preceding examples cite unfamiliarity with emergency procedures, ignorance of the regulations, and a disregard for the dangers which can accompany high-altitude problems. For the survival of crews, which in turn provides them the ability to care for their aircraft and its passengers, training should be provided in all aspects of high-altitude flying rather than just the rote learning of a proper emergency descent.

Although these reports do not represent the full spectrum of aviation, they do show that incidents occur which require that the crew have knowledge of high-altitude physiology and the dangers involved, the regulations governing those aspects of flight, and the proper procedures for dealing with emergencies. The reports also show that in many cases, *the crews appear to be lacking some part of* the knowledge required for safe operation in the high-altitude environment.

3. NATIONAL TRANSPORTATION SAFETY BOARD REPORTS

The National Transportation Safety Board (NTSB) answered our request for information regarding accidents/incidents involving flight physiology with eight reports from the time period 1973-1985. Of the eight reports, six dealt with specific accidents/incidents and two concerned special studies done by the NTSB. Summaries of all the reports can be seen in Appendix B. The special studies came about as a result of other accidents/incidents which generated common concerns about specific areas such as chemically generated O_2 systems. We were not given specific information about those accidents/incidents, and they could have been included in some of the other reports which we did receive.

While some of the reports dealt with fires, some with decom-pressions, and some with other safety concerns, all dealt with some form of oxygen system in some manner. The following are illustrative:

- An in-flight B-707 fire in 1973 resulted in 124 fatalities and total destruction of the aircraft after a successful emergency landing. The fire was fed by material from the aircraft interior. There was a shortage of protective breathing equipment (PBE) with full face masks to allow the crew to fight the fire. The lack of such equipment was addressed.

- A DC-9 in Cincinnati, Ohio, in 1983, had a fire in the left rear lav, made an emergency landing, and evacuated the aircraft. The material in the interior of the aircraft continued to burn during the descent and evacuation, and 23 passengers died. The NTSB cited a shortage of protective breathing equipment with full face masks in the passenger cabin and accessible to the crew. An ensuing amendment to the FARs required protective breathing equipment for all crewmembers. In addition, there is an ongoing study of respiratory protection for passengers from toxic environments during aircraft fires as a result of this accident.

As can be seen from the two previous report summaries, addressing a problem is not synonymous with solving it. Ten years after the B-707 fire, there were still insufficient protective breathing masks for the entire crew. This lack reduced the effectiveness of fire fighting efforts by the crew and might have led to greater loss of life.

While the lack of equipment was a concern of the above reports, other reports indicted lack of training and defective equipment. The following report excerpts are illustrative of those:

- Several rapid decompressions involving DC-10s and L-1011s have uncovered problems with chemically-generated O_2 systems. Most of the problems have been attributed to lack of understanding of the systems by both passengers and **flight attendants**.

- An in-flight fire on board a Singapore-bound L-1011 in 1985 led to the discovery of malfunctioning passenger O_2 system sequencing valves. Some of the O_2 masks were neither automatically presented nor were presented when the system was activated from the engineer's panel. An immediate Airworthiness Directive (AD) was issued to correct malfunctioning oxygen initiator sequence timer switches.

While hypoxia, gas expansion, and other physiological problems were not specifically addressed by the reports, these occurrences were still a probability, and some of them may have, in fact, been experienced by crew and passengers alike.

4. PHYSIOLOGICAL PROBLEMS AND FLIGHT CREW UNIONS

To ascertain flight crew union participation in the investigation of physiological problems affecting their members, seven unions were contacted by telephone. Two of these unions represented pilots and five represented flight attendants. To date, five have responded. We were unable to contact representatives for health and safety for APFA, representing American Airline flight attendants, and the APA, representing American Airline pilots.

ALPA, the largest of the unions, represents pilots on 50 different airlines. ALPA is well known for its active participation in safety-related matters, but it does not specifically keep files on flight physiology problems. Although flight physiology might enter into an investigation as a contributing factor to an incident or accident, ALPA does not treat flight physiology as a single factor and keep records on it.

The Association of Flight Attendants (AFA), is the largest of the flight attendant unions. Information received from them, indicates that they deal with physiological problems affecting their members on a case-by-case basis, by gathering information from member incident reports. If a significant number are received, or an apparent trend develops, they try to get the management of the company involved to take corrective action. For example, they have had 27 reported incidents of physiological problems in the recent past on one airline. The first 18 appeared to be aircraft specific since they all happened on MD-80 series aircraft. However, since that time there have been reports of similar symptoms on another aircraft type. The problems included nausea, severe headaches, disorientation, loss of motor skills, numbness, and other hypoxic symptoms, and appeared to be altitude related (most problems occurred with aircraft at a cruise altitude in the high 30,000 foot range, such as 35,000 or 37,000 feet). If the flight attendants brought the symptoms to the attention of the front-end crew when they first occurred, and if the front-end crew was able to make a descent of a few thousand feet, most symptoms were reported to have disappeared. However, in some cases, the symptoms lasted for days. A point of interest is that this airline flies much of its schedule in the higher latitudes where ozone problems are more prevalent (in the higher latitudes, the troposphere is lower and the ozone layer altitude varies with the troposphere). Some of the symptoms of excess ozone exposure are similar. To quote from an FAA report on the effects of ozone (FAA-AM-79-20), some of the effects included "marked changes in pulmonary function, malaise, muscle ache, cough, wheezing, sputum production, substernal pain, dyspnea (difficulty in breathing), fatigue, headache, laryngitis, and nasal discharge." Also, from the same report, were accounts of subjects whose symptoms lasted from less than four hours to three days. In the incidents cited by AFA, cockpit crews appeared not to be affected by the symptoms. This might be explained with another quote from the aforementioned FAA report; "Fewer complaints from flight deck personnel than from cabin personnel may be related to the fact that most pilots and flight engineers are males with relatively sedentary duties, whereas most flight attendants are females and are active in flight." (The report also concluded that females were more subject to the symptoms than males.) According to Richard O. Reinhart, M.D., in the January, 1989 issue of *Business & Commercial Aviation:* "Increased activity also will increase the need for oxygen by the body. Flight attendants on a busy trip can become hypoxic before the cockpit crew who are physically inactive." Although Dr. Reinhart is specifically talking about hypoxia, this would seem to parallel the FAA report quote regarding increased activity and ozone effects. Another consideration is the passengers. To again quote the FAA report, "...it is more likely that these conditions will occur in the passenger group, whose age and medical status are beyond the control or even knowledge of the airlines or the FAA."

The information regarding the recurrent flight attendant symptoms was brought to the attention of the airline management by AFA, with a request that it be investigated further and remedial action taken. The airline did a number of tests, including checking the ozone filters on the aircraft, with no conclusive results. The problems continue to be reported. Although they have not been able to supply us with copies of their files for documentation, they have submitted copies of recent media coverage of this series of problems. According to the articles, the airline has found nothing wrong and feels the union is fabricating problems. The media reports mentioned, however, that some passengers on the referenced flights had complaints of physical ailments similar to those of the flight attendants.

IFFA, the union representing TWA and former Ozark flight attendants, reported keeping files on many physiological problems. They participated with other flight attendant groups in what is reported to be a well-documented report regarding the physiological problems to be considered in duty rig regulations, such as fatigue and concerns related to high-altitude pressurized flight for extended periods. (Duty rigs govern such things as daily, monthly, and annual flight time, scheduled flight time versus actual flight time, scheduled time on duty, minimum scheduled rest time between trips, etc.) This report was submitted to the FAA for study (date unknown) but no definitive answer has been forthcoming. Other information currently being gathered by IFFA includes reports on cabin air quality and the long-term effects associated with jet flight. The latter are just beginning to surface and IFFA is interested in tracking them. IFFA also participates, as do other flight attendant unions, in quarterly meetings of the Coalition of Flight Attendants. This group was formed approximately five years ago to study new research and investigate reports of safety and health problems encountered by their members, many of which involve areas of flight physiology. Included in the group are counterparts from airlines in other parts of the world. The representative of IFFA with whom we talked reported that the Coalition received quite a bit of information from research being done in other countries. However, an apparent shortage exists of research information from sources in this country. This was an opinion reportedly shared by the flight attendant unions but we have been unable to get further specific information. IFFA is also involved in other physiology projects not related to altitude, such as galley cart design and the carpal tunnel syndrome involved in use of present design carts. The IFFA representative spoke of IFFA's willingness to share information and participate in any forum which would seek to better the safety and health of their members.

The IBT, Local 2707, represents flight attendants from Northwest and World Airlines, and the former Flying Tiger people who were absorbed by Federal Express. Although they also participate in the Coalition of Flight Attendant Unions, unlike IFFA, they do not keep extensive files on the information exchanged according to their representative. The only files which they keep pertain to individual cases involving litigation against an airline by one of their members. None currently on hand were relevant to our interest.

IUFA, the union representing Pan Am flight attendants, has kept files concerning member physiological problems for some time. They shared with us copies of files dating back as far as the late 1970s. Most related to poor air quality and/or circulation in aircraft cabins and mentioned a number of aircraft types from 747 to A310. The symptoms mentioned in the files range from typical hypoxic symptoms to pneumonia. Some were concerned with the effects of ozone on long, high-altitude flights, especially those in the higher latitudes. Others are concerned with low airflow in the cabin at cruise altitudes when passenger service is at its peak. Examples of this problem surface on the 747, which often cruises with only two packs out of three available packs in operation; with the L-1011, which has had complaints of poor air circulation in the aft cabin; and with the A-310, which has an Econo Fuel Valve which is supposed to reduce bleed air flow from the engines through the air conditioning packs in favor of better fuel economy. The latter supposedly affects both the volume of air and the rate at which the air in the cabin is circulated. This has produced many complaints of hypoxic symptoms from flight attendants during periods of high activity, such as a meal service with a full load of passengers. Also, when a number of passengers are smoking, the reduced air circulation is reported as being inadequate to keep the cabin relatively clear of smoke. Recurring physiological complaints of a similar nature have been forwarded to company management. The company has set policies which allow for maximum air flow to be used if requested by the purser, however this is reportedly not often followed, and the cabin crews report continuing to work in conditions of inadequate air flow. We found out from another source that when the aircraft is carrying over 165 passengers, it is company policy that the Econo Fuel Valve not be utilized. Another comment from this source indicates that because of aircraft capabilities, the aircraft is able to reach higher cruising altitudes earlier in the flight than older-generation aircraft, thus exposing crews to higher cabin altitudes for a longer period of time. This would be accentuated by coinciding with heavier cabin crew workload during meal service.

The above unions represent most unionized flight crewmembers in this country. Of the five responding unions, although three unions keep files on physiological problems, many of the files do not pertain to altitude-related physiology. IUFA sent copies of a number of their files on air quality. The reports detailed problems from inadequate air circulation in cruise which led to hypoxic symptoms, to concerns about ozone on extended high altitude, high latitude flights. The ozone reports gave examples of physical symptoms reported by flight crewmembers. IFFA has files on many issues regarding flight physiology, ranging from air quality to galley cart design. Their air quality files reportedly show the same concerns as those of IUFA, along with many of the same symptoms, and they have indicated a willingness to share any files we might request. AFA, does have some files but are not aware of any pertaining to this study other than the aforementioned ones dealing with reported hypoxic and other symptoms at cruise altitudes occurring on one airline. One common usage of all these files is to document problem areas for presentation to the airlines to seek to rectify the perceived problems.

None of the unions with which we spoke engaged in physiological education of their members, regarding that as a company function. However, all expressed concern about the physiological effects on their members of high-altitude flight in the short-term and the long-term. One apprehension concerned the ability of crewmembers suffering from short-term adverse physiological effects to adequately aid their passengers in the event of decompression.

5. AVIATION TRAINING CENTERS

Discussions were held with training personnel from nine aviation training schools to determine how many included flight physiology training in their curricula. The schools were selected from the list in the World Aviation Directory (WAD) and were chosen as examples of universities, colleges, and professional training organizations engaged in flight training. Four schools engaged in various phases of training from ab initio to corporate recurrent. Three were examples of university flight training departments which offered undergraduate and

	Ohio State Univ.	Simu-flite	Embry-Riddle	Flight Intl. Inc.	Univ. of North Dakota	Parks College	Flight Safety Intl.	Univ. of S. Calif.	Northwest Aerospace Training. Corp.
ALTITUDE RELATED									
Hypoxia	X	X	X		X	X		X	X
Trapped gases	X	X			X			X	X
Decompression & evolved gases	X	X	X		X			X	X
Oxygen equipment	X	X	X		X		simulator		
Altitude chamber use			available		included				
Time of useful consciousness at different altitudes	X	X	no mention		no mention			no mention	X
Ozone & radiation		X						X	ozone
OTHERS									
Stress	X		X		X			X	X
Visual problems	X	X	X		X			X	X
Spatial disorientation	X		X		X			X	
Attention anomalies	X		X		X			X	
Hyperventilation	X	X	X		X			X	X
Self medication	X		X		X			X	X
Effects of alcohol	X		X		X		X	X	X
Diet & nutrition	X		X		X			X	X
Fatigue	X				X			X	
Heat	X		X					X	
Acceleration	X		X		X				
Noise & vibration	X		X					X	X
Smoke & fumes	X				X			X	
CRM (recognition of symptoms)							X	X	

TABLE 1 - SCHOOL PHYSIOLOGY CURRICULA

advanced degree courses and preparation for FAA flight ratings; one of these has also done ab initio training for at least two airlines. The remaining two training centers were colleges that specialized in flight training and education - one with courses to provide preparation for FAA ratings of varying kinds; and one with degree-conferring courses of study which also provided preparation for FAA flight ratings.

The other schools contacted varied in their teaching of flight physiology, as can be seen in Table 1. Flight International, Inc., which does training from ab initio to corporate refresher and lists 22 locations for training, states that they do no training in flight physiology. Ohio State, Embry-Riddle, University of Southern California, and University of North Dakota are examples of schools which offer extensive courses of a semester or more in length.

Of the nine aviation schools, seven include some subjects in altitude-related physiology and teach hypoxia, its effects, and how to deal with it. The causes and effects of trapped gases are taught by five schools. Six include information on decompression and evolved gases. The use of oxygen equipment is a classroom subject for four schools and is addressed during simulator sessions by a fifth. The use of an altitude chamber to illustrate hypoxic effects and teach self-recognition is included in the course of study at one school and is made available to students at a second. The time of useful consciousness at various altitudes is mentioned at three schools, according to their curricula. The effects of ozone and radiation at varying altitudes and latitudes is included in course matter at two of the facilities; another does not teach radiation effects but does cover the effects of ozone.

Flight physiology curricula included subjects other than those related to altitude. Four schools had very extensive courses, as can be seen from Table 1. Six addressed visual problems, hyperventilation, and the effects of alcohol. Five dealt with stress, self-medication, and diet and nutrition. Four schools covered spatial disorientation, attention anomalies, and, noise and vibration. Three spoke to the effects of fatigue, heat, acceleration, and smoke and fumes. Two of the facilities had course material dealing with cockpit resource management

(CRM) as it pertained to the recognition of incapacitation in fellow crewmembers and the necessity to take action because of it.

Ohio State and Embry-Riddle have flight physiology courses as part of their academic curricula. The University of Southern California teaches flight physiology as a part of their "Aviation Safety Program Management" course. Individual aspects of flight physiology are taught in a number of their other courses, as well. The University of North Dakota has an ab initio course designed to take zero-time students and train them to entry-level standards for regional air carriers. They report having trained such pilots for Evergreen and Gulf Air, among others. Their curriculum includes a course in flight physiology, which is also made available to any of their other students, such as corporate and commercial recurrent students. North Dakota reports having the only altitude chamber not connected with the military or the FAA in this country. Flight Safety International teaches little flight physiology, only the effects of alcohol and hypoxia. The latter is taught only in their CRM course as it pertains to recognition of incapacitation. However, any of their instructors who will be teaching in jets are required to take an altitude chamber session, and they strongly recommend to their students who are transitioning into jets that they take a chamber ride also. Their instructors take the altitude chamber familiarization and ride given at the FAA's CAMI in Oklahoma City. Simuflite trains corporate pilots and has contracts with some government agencies to do training in small aircraft for them. Their jet indoctrination includes three days of high-altitude pilotage which incorporates two hours of flight physiology. The contents of all the mentioned courses can be seen in Table 1.

From the information received, it is apparent that there are organizations that do provide instruction in flight physiology. Some of them presently have longer courses than might be applicable for general civilian flight personnel education. However, more abbreviated courses could be developed. Other schools provide short courses. From the information on current flight physiology training that we received through our small sampling, and given the large number of schools available countrywide, it is clear that useful curricula currently exist for providing flight physiology training to airline and corporate flight crews and general aviation pilots.

6. AIRLINE FLIGHT PHYSIOLOGY TRAINING

FAR 121.417, "Crewmember Emergency Training," specifies in section (e) that "crewmembers who serve in operations above 25,000 feet must receive instructions in the following:

(1) Respiration.

(2) Hypoxia.

(3) Duration of consciousness without supplemental oxygen at altitude.

(4) Gas expansion.

(5) Gas bubble formation.

(6) Physical phenomena and incidents of decompression."

FAR 135.331(d) specifies exactly the same requirements.

To determine what training is being conducted in the airline segment of the industry, we gathered information on six airlines. Representatives of the training departments of four airlines responded with information on what training they carried out. Training at a fifth airline was recalled from personal involvement of one of the writers. Information on recurrent training for two airlines was presented by pilots from those airlines, and from a flight attendant representative of one airline we received information on flight attendant training.

All five airlines profess to meet the minimum requirements of FAR 121.417, but the depth and method of training varies widely. Two of the airlines use old GI films put in video tape format. One airline uses a combination of films, videos, slides, lectures, and handouts. Another airline gives all new-hire pilots a book on high-altitude jet flight. This encompasses many subjects, including flight physiology. This is presented to the pilots as mandatory reading, and is the only exposure to the subject that they receive in indoctrination. The training representatives with whom we talked were only able to provide information on pilot training, except for one airline where indoctrination training in flight physiology was identical for pilots and flight attendants, according to its training representative.

Recurrent training in the subject of flight physiology is required by FAR on an "as required" and "as appropriate" basis. This allows the airlines a great deal of discretion in the selection of subjects and the frequency of coverage. One airline does not cover all subjects on an annual basis but does go through the list of subjects in recurrent reviews on about a four-year cycle. Another airline does not have recurrent training in flight physiology. Other airlines review subjects when they are relevant to incidents that have occurred in the industry in the recent past, but provide no planned recurrent training in that subject.

Review of annual, recurrent-training, home-study materials from two of the five airlines was conducted by a pilot from each airline. The material from one airline consisted of quarterly handouts. A review of six handouts revealed three mentions of subjects related to flight physiology: (1) in a review of pressurization, the time of useful consciousness (TUC) for FL350 was given as an example; (2) another section presented a review of oxygen systems; and (3) one quarterly recurrent presented a table of TUCs at various altitudes. The annual, home-study, open-book exam for the other airline was reviewed for references to flight physiology by the pilot taking the recurrent exam. There was one question regarding explosive decompression and time of useful consciousness.

The actual use of oxygen equipment is practiced in simulator recurrent training for emergency descent in the event of rapid decompression. This training is mandated by FAR and is carried out on a semiannual basis for Captains and on an annual basis for other flight officers for the airlines studied, and presumably for all airlines.

Most of the airline representatives with whom we spoke had information regarding pilot training only and could give us no information regarding flight attendant training. One airline stated that initial training was the same for pilots and flight attendants with recurrent training directed to equipment more likely to be used by that group, i.e., quick-donning oxygen masks reviewed by pilots. One union representative sent copies of flight attendant manual excerpts regarding the training she had received. She stated that this material was representative of the indoctrination training received and was their sole reference for altitude-related flight physiology review. Three related subjects were covered: (1) the indications of cabin pressure loss and actions to be taken; (2) the symptoms of hypoxia; and (3) a chart of times of useful consciousness at various altitudes. The chart of TUCs showed times which were longer, and considerably longer in some cases, than those shown in another airline's chart or some of those in the *Bioastronautics Data Book.* What source the airline used for its information was not stated and the chart appeared to give information which would give crewmembers a false impression of the amount of time that they could function without supplemental oxygen. We feel this is information which should come from a common source for any airline and should be subject to POI review to assure that the correct information is presented.

Some concerns are raised by this review of flight physiology training by airlines. They are as follows:

The requirement for flight physiology training as stated in FAR 121.417 is for those crews flying above 25,000 feet - The *Airman's Information Manual* (AIM) states that "For optimum protection, pilots are encouraged to use supplemental oxygen above 10,000 feet during the day, and above 5,000 feet at night." Other experts in the industry agree with those figures. We have a great deal of concern over the apparent discrepancy between the AIM recommendations and the requirement for training only those crewmembers serving above 25,000 feet.

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. To quote FAA Advisory Circular 91-8B, "A common misconception exists among pilots who have not completed physiological training that it is possible to know the symptoms of hypoxia and then to take corrective measures once the symptoms are noted. This concept is appealing because it allows all action, both preventive and corrective, to be postponed until the actual occurrence. Unfortunately, this theory is both false and dangerous for the untrained crewmember, since one of the earliest effects of hypoxia is impairment of judgment. Although a deterioration in night vision occurs at a cabin pressure altitude as low as 5,000 feet, other significant effects of altitude hypoxia usually do not occur in normal healthy pilots below 12,000 feet. From 12,000 to 15,000 feet altitude, in addition to impairment of judgment, memory, alertness, and coordination being affected, headache, drowsiness, and either a sense of well-being or of irritability may occur. These effects increase with shorter periods of exposure to higher altitude." The following quote would seem to indicate the need for training in flight physiology for all crewmembers flying above 10,000 feet, regardless of the particular altitude flown above that. "In exposure to altitudes below 10,000 feet, the effects of hypoxia on the pilot are mild and acceptable. Above this altitude, human performance degrades very rapidly." (AC 91-8B) Another quote is even more specific: "Visual thresholds have been shown to increase at altitudes above 4,000 feet, probably because of the very high oxygen requirements of the light-sensing cells in the eye. Impairment of ability to learn new complex tasks has been demonstrated at 8,000 feet; impairment of recent memory, judgment and ability to perform complex calculations are seen at altitudes in the neighborhood of 10,000 feet (*Bioastronautics Data Book NASA SP-3006*)." In consideration of the aforementioned, perhaps the altitude mentioned in FARs 121.417 (e) and 135.331 (d) should be lowered to 10,000 feet.

There is a lack of altitude chamber training for airline flight personnel - Any pilot trained in the military is required to take altitude chamber runs for indoctrination and for recurrent. Recurrent training is on a three-year basis for the Army and the Air Force. The Navy is on a four-year recurrent cycle. If the individual pilot is scheduled for a new tour of duty in less than the scheduled recurrent cycle, they must take recurrent prior to the new tour of duty. Civilian pilots normally are not exposed to this training. The AIM says: "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.'" Since the military services require altitude chamber flights for their flying personnel and for passengers in some of their aircraft types, and the AIM recommends this training for recognition of hypoxia, we think it only logical that it be required by FAR that civilian pilots have at least an initial altitude chamber flight. 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. According to the spokesman we contacted, if this proves feasible, their intent is to replace most of their recurrent training altitude chamber flights with this use of gases. We are told, however, that this is not an official Navy position. 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 amount of training given flight attendants versus pilots seems to vary - From the reports of flight attendant union representatives, we were given the impression that although the letter of the FARs might have been met in indoctrination, the depth of knowledge resulting was less than that of the pilot group. Although the job functions are not similar, it has been suggested that flight attendants are more subject than pilots to the effects of hypoxia because of their higher activity level during flight. They must also deal with passengers who might be subject to hypoxia. For these reasons we feel that flight attendants should receive as thorough training in altitude-related flight physiology as pilots.

The subject matter required by FAR for flight physiology training does not cover some subjects relevant for safe operation - The subject list covered in military flight training is more extensive and includes a number of subjects covered also in the section on "Fitness For Flight" in the AIM. We feel that subjects such as acceleration and force fields, stress, fatigue, and spatial orientation should be included in flight physiology training for pilots. Since most of these are not pertinent to the flight attendant job, training for that group in these subjects should not be necessary.

The FARs leave a great deal of room for interpretation regarding the necessity and frequency of recurrent training in flight physiology - Flight physiology training is mandated "as required" and "as appropriate." We feel that the FARs should specify a time period within which all required subjects must be reviewed by all flight crewmembers.

The subject matter presented in indoctrination by the airlines contacted appeared to cover the requirements set out by the FARs for flight crewmember training. The degree to which the subjects were covered varied widely, and the effectiveness of each program was impossible for us to judge. The amount and frequency of recurrent training in those subjects also varied. Although our sampling of airlines was quite limited, we feel that it provides a good example of what goes on in the industry. We also feel that serious consideration should be given to the following:

- Times of useful consciousness tables should emanate from a single, authoritative source and should be common throughout the industry.

- Training mandated by the FARs should be for any flight crews flying above 10,000 feet as opposed to the present 25,000 foot requirement.

- Training for recognition of hypoxia should be required for civilian pilots. Ideally, this could take the form of altitude chamber flights or the use of mixed gases as is being investigated by the Navy.

- Training given flight attendants should be as thorough and informative as that given pilots. While the training could be oriented more specifically to each task, the basic information on flight physiology should be the same.

- Recurrent training in altitude-related flight physiology should be mandated at specific intervals by FAR and should review all subjects required for initial indoctrination.

7. TRAINING BY OTHER GROUPS

In order to determine what physiology training was done in aviation other than by the airlines, we contacted Beech Aircraft Corp., Cessna Aircraft Co., Gulfstream Aerospace Corp., Mooney Aircraft Corp., Piper Aircraft Corp., the Aircraft Owners and Pilots Association (AOPA), the National Business Aircraft Association (NBAA), the U.S. Air Force, the U.S. Army, and the U.S. Navy.

Four of the airframe manufacturers provide contract training for new customers at delivery of the aircraft. Beech, Cessna, and Mooney provide customers that are taking delivery of an aircraft with a check-out at the nearby Flight Safety International facility. (As can be seen from the section on schools and reference to Table 1, Flight Safety International provides no altitude-related flight physiology training with the exception of the proper use of an oxygen mask. They discuss the recognition of hypoxic symptoms in other crewmembers as a part of CRM courses for multiple-crew aircraft. The effects of alcohol at altitude are also mentioned.)

Gulfstream varies the training as a function of what the customer requests and what the contract amount calls for. The basic contract calls for pilots to have two weeks training at the local Flight Safety International facility with additional training in the aircraft with Gulfstream training personnel. Once again, a minimum of flight physiology training is involved. However, Gulfstream recommends strongly to each customer that they get additional training in flight physiology. Since the training is not required by FAR and is an expense to the customer, Gulfstream philosophy is to recommend and leave it to the customer to follow through. Since most of the pilots for their customers are former military, they have had prior training in most aspects of flight physiology and would need recurrent training only.

Piper provides aircraft check-out for their customers with their own personnel. For customers buying pressurized aircraft, training is given in the use of the pressurization system. There is also brief mention made of hypoxia and time of useful consciousness (TUC) at altitude without oxygen, according to a Piper spokesman. Piper has in their inventory a pressurized turbo-prop, the Cheyenne 400, which is capable of altitudes up to 41,000 feet. The nominal TUC at that altitude is 10-16 seconds. If the aircraft sustains a rapid decompression, the pilot needs to recognize the event immediately and take action to sustain life very quickly. For this reason, Piper recommends that its pressurized aircraft customers take an altitude chamber ride. While FAR 91.32 mandates when oxygen must be used, it does not require training in depressurization or other altitude-related physiology.

A point of interest is that Beech and Cessna send their own pilots to the Civil Aeromedical Institute (CAMI) in Oklahoma City for training in high-altitude physiology, including a ride in the altitude chamber. Beech requires this before a pilot becomes aircraft commander in any pressurized aircraft. No schedule is set for this. When they have a group that needs the training, they transport them to and from the one-day course. At Cessna this is not mandatory, but is also done on an irregular schedule. Cessna pays all expenses incurred and provides transportation. Most of their pilots are former military and have had this training before, but Cessna feels the recurrent is important. Piper also recommends this to their pilots when and if they can do it, and suggests taking refresher at nearby MacDill Air Force Base.

AOPA was contacted to determine if flight physiology training was something which they offered their members. The spokesman with whom we talked said that they had no involvement in that.

The NBAA spokesman said that at present, they do no training in flight physiology. They do have annual four-day seminars for different groups within their membership (e.g., pilots, maintenance, management), and said they would like to have information on flight physiology to present at those seminars involving aircraft flight crews.

The people contacted who provided the most information on flight physiology training were those in the military. Military pilots receive the most thorough training in physiology and the information that the services sent to us was quite complete.

The U.S. Air Force structures their physiology training somewhat differently for members of the three basic groups of pilot and other flying personnel. The groups are (TARF) trainer, attack, reconnaissance, fighter; (TTB) tanker, transport, bomber; and (L&S) low and slow. Since the only two which would have parallels in civilian flying are the TTB and L&S groups, only those are represented here. Pilots receive a 46-hour curriculum in Undergraduate Pilot Training (UPT) with four altitude chamber flights. Navigators receive a 50-hour curriculum with three chamber flights. Other members of the primary crew receive the 24-hour original course with three chamber flights. Operational support flying personnel receive a 12-hour course with two chamber flights.

There are minor variations in the academics for the two groups. The TTB group receives additional training in crew coordination (CRM) and situational awareness. The L&S group receives additional emphasis on noise, vibration, and low-altitude hypoxia. Altitude chamber training in initial training consists of the specified number of rides, including a high-altitude rapid decompression flight, and includes altitudes to 43,000 feet. When pilots enter advanced training in the T-38, additional training is received. At the time of assignment to a squadron, further specialized training is received in the aircraft to be flown. The general subjects covered in initial training consist of the following:

Physiological effects of altitude. This covers the characteristics of the atmosphere; anatomy and physiology of circulation and respiration;

circulatory and respiratory responses to environmental stresses; hypoxia and hyperventilation, their causes, prevention, recognition, and treatment; and the physiology of trapped and evolved gas problems, including cause, prevention, recognition, and treatment.

Human factors. Covered are self-imposed stresses, oxygen discipline (the use of masks at the proper times), alcohol, carbon monoxide, blood donation by the pilot and the effects thereof, shock, extremes of temperature, diet, dehydration, drugs, fatigue, circadian rhythms, physical fitness, and psychophysiological factors (excessive motivation to succeed, over-confidence, personal problems, supervisor and peer pressure, task saturation, and anomalies of attention.)

Oxygen equipment. Deals with the various types of oxygen masks and regulators; aircraft oxygen systems; gas, liquid, on-board oxygen generation systems and chemical oxygen; servicing procedures; and the emergency use and inspection of this equipment.

Cabin pressurization and decompression. Teaches the principles of cabin pressurization, rapid and slow decompression and their hazards, and the precautions to take. Includes procedures to be followed after any cabin depressurization and their physical and physiological consequences.

Pressure breathing. Deals with the need for pressure breathing, its limitations, pressure breathing techniques, and the precautions to take.

Principles and problems of vision. Teaches the basic anatomy and physiology of day and night vision, factors affecting vision, dark adaptation, scanning methods, and flashblindness. Includes a demonstration in the night vision trainer and practice in methods of improving night vision.

Spatial disorientation and other sensory phenomena. Teaches how the body orients itself on the ground and compares this with the effects of flight. Includes an explanation of the central and peripheral visual modes and their effects on orientation. Also, covers problems associated with the distortion of plexiglas, size and distance illusions and motion sickness. All undergraduate flight trainees are given a ride in the spatial disorientation demonstrator.

Noise and vibration. Teaches the basic anatomy of hearing. Discussion includes the harmful effects of exposure to hazardous noise and vibration, and means to avoid overexposure.

Speed. Deals with aeromedical aspects of high-speed flight, aircraft ejection, flight instruments, cockpit temperatures, closure rate, visual problems, etc.

Acceleration. Teaches the physical and physiological effects of accelerative forces (G-forces), human tolerance, and means used to raise G tolerance and endurance.

Prechamber flight indoctrination. Teaches the purpose of the altitude chamber flight and the chamber flight profiles.

This listing does not include training not pertinent to civilian aircraft such as use of ejection seats and escape procedures. However, it does include training which is not directly altitude related which illustrates the thoroughness of training which exists in the Air Force and the emphasis that they place on all aspects of flight physiology.

Recurrent training for Air Force flight crews is normally scheduled every three years. However, if a flight crewmember is to be assigned overseas for a period of 36 months or less and currency in flight physiology training and altitude chamber will expire when they are overseas, they must renew their currency prior to deployment. Recurrent training includes a six to eight hour academic refresher tailored to the specific major weapons system and a ride in the altitude chamber. The L&S group covers self-medication, alcohol, diet and nutrition, heat, fatigue, including that generated by noise and vibration, trapped gas, decompression sickness, hypoxia, hyperventilation, smoke and fumes, anomalies of attention, air crew coordination training, and spatial disorientation. The TTB group academic recurrent includes air crew coordination training, alcohol, anomalies of attention, effects of dehydration (heat), hyperventilation, evolved gas decompression sickness, smoke and fumes, and spatial disorientation. The recurrent altitude chamber flight also differs between the two groups. The recurrent chamber ride for the L&S group does not involve altitudes as high as that for the TTB group.

The U.S. Army School of Aviation Medicine at Fort Rucker, Alabama does flight physiology training for Army fixed and rotary wing pilots, foreign military students, U.S. Air Force rotary wing pilots, and EURO/NATO rotary wing pilots. They process about 8,000 pilots per year and have the anecdotal reputation of giving the best training available. The academic subject matter covered is basically the same as that covered by the Air Force, and the interval for recurrent is the same, three years. The Army provides the same three chamber rides as the U.S. Air Force to Initial Entry Rotary Wing Air Force pilots which include a high-altitude rapid decompression and altitudes to 43,000 feet. One difference in the instruction is the altitude chamber training. The Army training uses 25,000 feet to demonstrate hypoxia and 18,000 feet to illustrate night vision problems.

The U.S. Navy changed their physiology program about eight years ago. From the information given us during telephone conversations with the Navy, and from the lesson plans submitted to us, it appears that their program uses more of a "shotgun" approach (according to their spokesman) than the Air Force and the Army. They cover more subjects in broader detail. Lessons on the following topics are given in indoctrination:

- Hypoxia.
- Hyperventilation, trapped gases, and decompression sickness.
- Stress.
- Self-imposed stress.
- Spatial orientation.
- Visual problems.
- Night vision, including spatial orientation demo.
- Acceleration and force fields.
- Oxygen equipment.
- Altitude chamber brief.

Other subjects included in indoctrination deal with survival, ejection seats, egress training, etc. but have no pertinence for this study. These subjects are all used for recurrent training, but the amount of coverage is left to the instructor to determine according to the amount of time he has available.

Altitude chamber rides are required for all Navy crewmembers in initial training, but not for helicopter pilots thereafter. Recurrent training takes place every four years or with each new operational tour of duty, whichever is less. The Navy altitude chamber ride involves altitudes lower than the other two services. The Navy currently is using what they term "Sneaky Pete" runs. The chamber starts at 8,000 feet and pressure is bled off slowly to not more than 25,000 feet to demonstrate the effects of a slow aircraft pressure leak. This provides a good demonstration of the effects of hypoxia but doesn't stress the body as much as the high-altitude chamber runs. The Navy is considering a feasibility study to assess the use of mixed gases in lieu of altitude chamber flights in response to a 1989 Naval Aviation Physiology Program Review. According to a Navy spokesman, the mixed gases could be used in simulators and would allow recurrent training throughout the fleet without the use of altitude chambers. The thought is to give indoctrination, and perhaps the first recurrent, in the altitude chamber, and any further training would use inert gases to provide the hypoxic effects. We have been told that this is only a consideration and not an official position. According to the Navy spokesman with whom we talked, the U.S. Air Force and the Canadian services investigated the use of gases and decided not to pursue it. According to an Air Force spokesman "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."

One other change in Navy training includes the introduction of cockpit resource management. Its inclusion is being urged by a former Navy flier, now a civilian and experimental psychologist.

In investigating the other sources of training and depth of training provided in other areas of aviation besides the airlines, it seems obvious that the greatest amount of training is being done in the military. While a good deal of the academic training they provide is not directly related to altitude, they feel the other subjects have sufficient importance to warrant inclusion in initial indoctrination and recurrent training. The subjects they include in their curricula and the emphasis placed on them and exposure to an altitude chamber might serve as a model for a core curriculum for flight physiology training in the civilian sector.

8. EXPERT OPINION PAPER REVIEW

The Expert Opinion Paper presented in Appendix A represents the views of a retired USAF fighter instructor pilot well versed in USAF flight physiology training. Joseph L. Vogel is currently employed as an Adjunct Assistant Professor teaching flight physiology in the aviation department of a major university. The recommendations he made in this paper are listed below with our comments.

> It is my recommendation that the basic core curriculum be the same for all pilots regardless of their ratings or the type of equipment they are flying.

We basically agree with this position. Our recommendation would require this for any pilot likely to operate above 10,000 feet.

> All pilots should receive a thorough academic indoctrination concerning physiological problems that relate to reductions in performance with the onset of a hypoxic condition.

The effects of hyp xia and how they affect each individual should be a required part of the core curriculum.

> All pilots should receive training about factors that produce performance decrements such as stress, sleep deprivation, fatigue, alcohol and drug use. Smoking, diet, and aging should be a part of the course. Recognition of those symptoms, and the corrective actions that must be taken, should be a centerpoint in the course.

These recommended additions to the core curriculum are very similar to our recommendations made in the report summary. Although we recognize that not all of these are altitude-related physiological concerns, they are of sufficient importance to warrant inclusion in the expanded curriculum.

> **Any person who is to fly any aircraft capable of operating in the Physiological Deficient Zone (12,000 to 50,000 feet) or above should be required to take a full physiological training course including the altitude chamber "flight" and to continue to receive recurrent training at least once every five years.**

We found evidence to support the addition of altitude chamber flights to mandated training (see SUMMARY). The interval between recurrent training periods is not a subject on which many agree. Mr. Vogel indicated that the Air Force School of Aviation Medicine may be recommending a five-year interval between recurrent training sessions. However, the Chief, Aerospace Physiology of the Surgeon General's Office of the Air Force states: "At this time, the USAF School of Aerospace Medicine would have no basis for recommending a change in training frequency, either greater than or less than every three years." The Army recurrent training interval is the same as the Air Force and the Navy has an interval of four years. On the subject of recurrent training in flight physiology, we tend to agree with the majority and feel that three years is a good interval.

> All pilots should receive training and be able to recognize that adequate nutrition and good physical conditioning also play a significant part in the pilot's capability to fly safely.

These are also good subjects for inclusion in the expanded curriculum.

> Recommend that items beyond the core curriculum for instrument-rated pilots flying aircraft capable of blind flight would cover spatial disorientation, visual illusions, and false sensations. Pilots should experience disorientation in the Barany Chair, the Vertigon or the Vertifuge wherever possible.

> One exception to the equipment hypothesis would be the proposed requirement that all flight instructors be required to take the full academic and chamber flight curriculum.

We agree that the academic subjects mentioned should be included in the expanded curriculum. However, we do not feel that exposure to these subjects should be limited to only instrument pilots or instructors. A ride in the Barany Chair, the Vertigon, or the Vertifuge could provide additional experience; however, the additional expense involved could prove prohibitive for the general pilot population.

> Recommend that commercial pilots and airline transport pilots be required to take the full course

including the altitude chamber, the Barany chair, and rapid decompression.

We recommend that all pilots be required to take expanded flight physiology training. We feel that the addition of altitude chamber training, including a rapid decompression, to that academic training can be supported. As mentioned above, although the Barany Chair could provide valuable experience, it might not be cost effective for many pilots.

9. ADDITIONAL PHYSIOLOGICAL CONCERNS

There are three subjects not yet addressed in this report which fall within the purview of altitude-related flight physiology. One deals with the FAR requirements for oxygen use by pilots operating under Parts 91, 121, and 135. Another deals with radiation exposure at high altitudes and high latitudes. The third deals with flying after scuba diving.

FAR 91 allows a pilot of an unpressurized aircraft to fly between 12,500 and 14,000 feet, for a period not to exceed 30 minutes, without using oxygen. For any flight above 14,000 feet, the pilot must use oxygen. FARs 121 and 135 differ from this as follows: the 30 minutes allowed without oxygen is between 10,000 and 12,000 feet, and above 12,000 feet oxygen must be used. For the purposes of emergency descent of a pressurized aircraft, Part 91 states that above 35,000 feet, one pilot must wear and use an oxygen mask unless both pilots are at the controls and have available quick-donning masks. Parts 121 and Part 135 require the use of a mask by one pilot above 25,000 feet unless both pilots are at the controls and have quick-donning masks available. However, Part 135 requires one pilot to wear a mask at all times above 35,000 feet, whereas Parts 91 and 121 require one pilot to wear a mask above 41,000 feet. The inequities in the requirements for pilots operating under different FARs is puzzling. A corporate pilot operating a B-727 under Part 91 is no less susceptible to hypoxia than an airline pilot flying the same equipment. And, a total incapacitation leading to an aircraft accident might be no less catastrophic in either case. We recommend that the FARs be revised to reflect a single standard for oxygen use regardless of whether an aircraft is operated under Part 91, 121, or 135.

The subject of radiation exposure at higher altitudes and higher latitudes is a matter of concern to flight crews. Recent media exposure on the subject brought the matter to public attention in articles in the New York Times in February, 1990. One article quoted the maximum allowable annual exposure for nuclear workers as 500 millirem per year. They went on to quote a draft memo from the FAA stating that flight crews working an Athens-New York route, with en route times in excess of nine hours and altitudes up to 41,000 feet, would accumulate 910 millirem per year. While this is not representative of all flight crews, it is indicative of a problem that needs further study. To put this somewhat in perspective, the same article quoted the National Council on Radiation Protection and Measurements as recommending to the government that the maximum allowable exposure for the general public be lowered to 100 millirem per year. Much has still to be learned about this problem and the long-term effects involved, and we recommend further study to accomplish this and to eventually set standards for flight crew exposure to radiation. It has been suggested that the expertise available in the Armed Forces Radiobiological Research Institute (AFRRI) and the Aerospace Medical Association (ASMA) could be utilized as research resources.

Scuba diving has become a very popular sport in recent years and is often enjoyed by flight crews on layovers in warm climates. Since the gases inhaled in scuba diving remain in the system for a significant period of time, flying soon after scuba diving can lead to decompression sickness. We quote from the Airman's Information Manual:

1. "A pilot or passenger who intends to fly after scuba diving should allow the body sufficient time to rid itself of excess nitrogen absorbed during diving. If not, decompression sickness due to evolved gas can occur during exposure to low altitude and create a serious in-flight emergency.

2. The recommended waiting time before flight-to-cabin pressure altitudes of 8,000 feet or less is at least four hours after diving which has not required controlled ascent (nondecompression diving), and at least 24 hours after diving which has required controlled ascent (decompression diving). The waiting time before flight-to-cabin pressure altitudes above 8,000 feet should be at least 24 hours after any scuba diving."

10. SUMMARY

The first task of this report is to determine the need for training in altitude-related physiology for air carrier and general aviation flight crews. These should include recreational and business Part 91 pilots, Part 121 and 135 pilots, and flight attendants. To help establish this need for training we quote the following:

> *Bioastronautics Data Book NASA SP-3006* - "Visual thresholds have been shown to increase at altitudes above 4,000 feet, probably because of the very high oxygen requirements of the light-sensing cells in the eye. Impairment of ability to learn new complex tasks has been demonstrated at 8,000 feet (P_B 565mm Hg) (Ledwith and Denison, 1964); impairment of recent memory, judgment and ability to perform complex calculations are seen at altitudes in the neighborhood of 10,000 feet (P_B 520 mm Hg) (McFarland, 1953)."

> According to J. Ernsting, Ph.D., of the Royal Air Force Institute of Aviation Medicine, "The most important single hazard of flight at high altitude is hypoxia." To continue, "The results of the 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 is 8,000 ft. This conclusion is reflected in the United Kingdom by the current Royal Air Force Regulations covering the use of oxygen in unpressurised (sic) aircraft. Thus aircraft not fitted with oxygen equipment are not to be flown above 10,000 feet; where practicable, they are not to be flown above 8,000 ft. These regulations may be compared with the regulations of the United Kingdom Civil Aviation Authority which allow pilots of private aircraft to fly for up to 30 min. without oxygen at altitudes between 3048 and 3962 m (10,000 and 13,000 ft.). The corresponding regulations of the United States Federal Aviation Agency (sic)(FAA) for the crew of unpressurised private aircraft allow even greater hypoxia. Thus the minimum standard required by the FAA is that oxygen shall be used at and above 3657 m (12,000 ft.) but pilots may fly for 30 min. without oxygen at altitudes between 3810 and 4267 m (12,500 and 14,000 ft.). It is believed that these civil regulations are too lax and that they should be amended to reduce the maximum altitude at which pilots can breathe air towards, and eventually below, 10,000 ft."

These quotes show the concern surrounding the physical incapacitation, partial or complete, which could occur due to hypoxia at altitudes 4,000 feet and above. This concern is escalated by the following quote from an article entitled "HYPOXIA: the unlikely event?" in *Flight International*, 8 April, 1989:

> Dr. Alistair MacMillan, Head of the Altitude Division of the Royal Air Force Institute of Aviation Medicine says, "In an actual decompression at 25,000 ft. (sic) the partial pressure (of oxygen) drops immediately. The residual oxygen in the bloodstream and lungs is thus 'dumped overboard' immediately, so the body is in a worse position than was previously thought. Instead of simply not taking in oxygen, the body is actually dumping it. The onset of the symptoms of hypoxia is therefore much faster than was previously thought."

It has been indicated earlier in this report that there are physiological conditions other than hypoxia which could lead to incapacitation, e.g., expansion of gases and gas bubble formation (decompression sickness). The inability in pilots and other flight crewmembers to recognize symptoms of hypoxia and other physiological problems could lead to total incapacitation and potentially fatal aircraft accidents. This is borne out by accident reports from a number of sources, including the National Transportation Safety Board (NTSB) and Aviation Safety Reporting System (ASRS). For this reason, we feel very strongly that training of civilian flight crewmembers, including flight attendants, and general aviation pilots in the subject of flight physiology is necessary and should be mandated by FAR.

The addition of altitude chamber flights to that mandated training would seem to be supported by the following quote from an article in *Aviation, Space and Environmental Medicine* by Dr. C.J. Brooks of Maritime Command Headquarters, FMO Halifax, Nova Scotia, Canada.

> "Loss of pressurization is an extremely low, but definite risk to the pilot and passengers, thus aeromedical training with practical demonstrations in the hypobaric (altitude) chamber for aircrew and flight attendants should continue."

The second task of the report is to review current training practices in the industry and academia. Aviation training schools have courses ranging from one-day recurrent training classes to four-year degree-conferring colleges. Most of these include flight physiology in their subject matter, however briefly. To provide additional information in this field, we commissioned an expert opinion paper (Appendix A). The writer is currently teaching flight physiology at a major university. He is also a retired Air Force fighter pilot instructor well-versed in USAF flight physiology.

The scheduled airlines are required by FAR 121 or 135 to teach the six subjects listed in the FARs to their crews flying above 25,000 feet. Reports from airline training personnel and crewmembers indicate that the training ranges from nonexistent to minimal.

Other sources of flight physiology training such as the Civil Aeromedical Institute (CAMI) are used by some corporate aviation departments for refresher training and are available to others on request.

The third task of this report is to develop a curriculum that can be used to provide the training that appears to be necessary. At present, the FARs mandate that flight crews operating above 25,000 feet receive instruction in the following subjects:

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

We feel that the use of oxygen equipment, both fixed and walk-around, should be added to that list of altitude-related subjects, and that the mandated altitude should be lowered to 10,000 feet.

We also feel that the following subjects addressed by training in the military and by some civilian schools should be added to the curriculum, despite the fact that they may not be altitude related. Some of these subjects are also addressed in the AIM.

- Flying after diving.
- Stress - external and self-imposed.
- Illusions in flight, especially those leading to spatial disorientation. The AIM says "Illusions rank among the most common factors cited as contributing to fatal aircraft accidents."
- Visual problems and night vision.
- Acceleration and force fields.
- Carbon monoxide poisoning in flight.
- Human factors, including self-medication, smoking, use of drugs and alcohol, fatigue, nutrition, physical fitness, and dehydration.
- Hearing, noise, and vibration.

As presently written, the FARs reflect dissimilar requirements for pilots operating under different Parts of the FARs. We recommend that the FARs be revised to reflect a single standard for oxygen use regardless of whether an aircraft is operated under Part 91, 121, or 135. Perhaps a common ground could be reached by using the standards currently specified in Part 121 as a basis for all operations.

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APPENDIX A

AN EXPERT OPINION PAPER ON HIGH-ALTITUDE PHYSIOLOGY TRAINING FOR CIVILIAN PILOTS

by

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INTRODUCTION

The requirement for training in high-altitude physiology for civilian pilots has not been a part of their training curriculum for a number of reasons. Basically, throughout aviation history, most civil flying has occurred at the lower, or relatively physiologically-safe altitudes. With the advent of turbo-charged equipped aircraft engines mounted on airframes that are unpressurized, the need for physiological training increased. Even though most civil flying still occurs at the lower altitudes, there are specific actions that pilots take before flight that can raise the effective altitude of their bodies and subject them to the same dangers that occur at much higher altitudes.

The lack of physiological training becomes more acute when pilots fly in pressurized aircraft above 25,000 feet. The insidious effects of lack of oxygen, when pressurization is slowly reduced, such as would occur with a minor leak in the system or a less-than-catastrophic failure can cause problems. Minor illnesses, impaired judgement, memory and alertness, and the effects of medications on the body and brain makes high- altitude flying too dangerous for untrained pilots and their passengers.

When pilots combine their private flying skills with their business transportation needs and use their aircraft to meet those needs, it is inevitable that in order to meet a schedule, arrive at a destination, or get home after a meeting, the urge to complete a mission will lead the pilot into a physiologically-unsafe altitude or into conditions for which there has been insufficient training or experience.

Recently, a new trend has taken place in commercial and airline aviation. Formerly, the airlines and many of the commercial or corporate operators have relied upon military-trained pilots to fly their aircraft. These military-trained individuals have had the benefit of an extensive physiological training program and have carried that expertise into their civilian jobs. Now, with the forced retirement of airline pilots at age 60, and former military pilots of the Korean War era reaching that age, a large number of pilots are retiring each year, creating a strong need for new pilots to enter the field. Airline deregulation has resulted in many new airliners being purchased, new routes being flown by established airlines, and feeder or commuter airlines increasing their market share and consequently, their need for pilots.

To further exacerbate the shortages, the military services are not producing as many pilots as in previous times and those that do enter the service are faced with lengthened commitments. For instance, in April 1990, the United States Air Force lengthened a pilot's service commitment from 8 years to 10 years after pilot training. The net effect is to slow the movement of military-trained pilots from the services to the airlines.

It is estimated by the Future Airline Pilots Association (FAPA) that as many as 6000 new airline hires will be needed each year for the next 10 years to meet the demand. The obvious answer to that shortage is that pilots will have to come from civilian-trained sources. Those sources range from individual flight instructors operating with one airplane "out of the trunk of a car" to fixed base operators with Part 141 schools, to the Flight Departments maintained as academic institutions in leading universities.

Even though a pilot may fly aircraft that are incapable of climbing above the physiologically-safe altitudes, their need for information and training concerning physiological phenomenon still exists. The need for high-altitude physiology training for civilian pilots becomes more important as they begin to take their places flying high-performance aircraft. With the advent of more sophisticated general aviation aircraft becoming available on the used aircraft market at reasonable prices, the need for training becomes even more acute. When the current crop of single-engine, pressurized, turbo-charged aircraft such as the Piper Malibu become more widely used, and the trend toward single-engine turbo-prop planes such as the TBM 700 come into wide use, the personal high-altitude-capable general aviation aircraft will be a reality. TBM plans to sell four of these aircraft per month with the United States being the target market.

The problem of whether to require physiological training for private pilots should be beyond argument. What can be argued is the type of training to be required and to whom should it be applied. This paper will primarily address flight physiology as affected by altitude; however, other aspects of flight physiology will be included as suggestions where additional training may be required. The goal is to produce a safe, efficient, and competent pilot.

CURRENT REGULATORY REQUIREMENTS

The requirements for physiological training for individuals who aspire to the private pilots license is, at best, minimal. The Federal Aviation Administration (FAA) *Private Pilot Practical Test Standards* booklet for Airplane single-engine land (FAA-S-8081-1A) is admittedly task oriented. Moreover, they treat "AEROMEDICAL FACTORS" as "Task F." (The last in the lineup) in the preflight preparation Area of Operation. The objective of this area is that the applicant for a pilot's license:

"Exhibits a knowledge of the elements related to aeromedical factors, including the symptoms, effects, and corrective action of -

(a) hypoxia.
(b) hyperventilation.
(c) middle ear and sinus problems.
(d) spatial disorientation.
(e) motion sickness.
(f) carbon monoxide poisoning."

The objective section goes on to suggest that the pilot applicant have knowledge of the effects of alcohol and drugs and their relationship to flight safety, and the effects during flight of nitrogen excesses derived from scuba diving.

CURRENT TRAINING

(How is Flight Physiology Being Taught in the Civilian Sector?)

In order to accurately portray what flight physiology subjects are being taught in the civilian sector and how they are being taught, one must first understand the types of training that can be obtained in the civilian sector. First, all aspirants to pilot and flight instructor certificates and ratings must comply with the requirements set forth in Federal Aviation Regulation (FAR) Part 61. FAR Part 141 schools must comply with somewhat more rigid requirements but the basic rules are contained in FAR Part 61. It is important to note here that anyone who passes the appropriate written and flight examinations, and is otherwise qualified, may obtain a pilot's certificate. Furthermore, that person need not have attended any formal school, informal classes, or other academically-oriented study group to obtain the licenses and ratings. According the FAR Part 61.105:

"An applicant for a private pilot certificate must have logged ground instruction from an authorized instructor, or must present evidence showing that he has satisfactorily completed a course of instruction or home study in at least the following areas of aeronautical knowledge appropriate to the category of aircraft for which a rating is sought."

The FAR proceeds to outline the aeronautical knowledge appropriate to each category of aircraft for which the rating is sought. No mention of knowledge of physiological problems or procedures is presented in the outlines.

The key words "home study" indicate the lack of formal education needed to become the pilot of a high-performance aircraft. Persons who are trained under Part 61 of the Federal Aviation Regulations therefore are not considered by the Federal Aviation Administration to have any need for formal physiological training.It is also important to note that flight instructors are not required to undergo a formal school for their profession. There is, in fact, no provision in FAR part 61.181 through 61.187 indicating that an applicant for a flight instructor rating must know about physiological subjects.

Pilots are responsible for the basic flight information and ATC procedures for use in the National Airspace System (NAS) of the United States. The Airman's Information Manual (AIM) provides that information, however, it also contains items "...of interest to pilots concerning health and medical facts..." but does not make these items mandatory reading.

Chapter 7 of the AIM is entitled, "Medical Facts For Pilots" and does address fitness for flight, effects of altitude, hyperventilation in flight, carbon monoxide poisoning in flight, illusions in flight, vision in flight, aerobatic flight, and judgement aspects of collision avoidance. All of this takes place within six pages in a very large manual devoted to the "mechanics" of flying.

The *Flight Training Handbook*, AC 61-21A, published by the Department of Transportation, Federal Aviation Administration, Flight Standards Service contains less than four full pages of "Aeromedical Factors." The section on Hypoxia contains two paragraphs. In fact, at four paragraphs, **more space is devoted to hyperventilation than to hypoxia.** Pilots are reminded however, that they should know more about this subject. To quote from AC 61-21A, "It is the responsibility of the pilot to consider the status of his or her personal health and to be informed on aeromedical facts. Advisory Circular 67-2, *Medical Handbook for Pilots*, provides much of this information."

Advisory Circular 67-2 is a very comprehensive and easy to read treatise on the physiological factors of concern to people who fly. It deals with subjects ranging from the physical examination to the flying passenger. In all, the subjects are adequately covered, however, one criticism is that it does not offer the subject an understanding of how the body is constructed and therefore why we behave the way we do when deprived of oxygen. Knowing these two things, the how and the why adds credence to the argument for supplemental oxygen at the higher altitudes, and provides a convincing argument for further investigation and training.

Merely stating that lack of oxygen will cause a certain set of symptoms and have a probable effect is no substitute for actually experiencing the symptoms and observing the effects of lowered atmospheric pressure. AC 67-2 should be taken for what it is, i.e., an Advisory Circular and not a regulation that must be read and obeyed.

AC 67-2 states in Chapter 4, Hypoxia, "Lack of oxygen is the greatest single danger to man at high altitudes, despite the importance of pressure and temperatures." Pilots are expected to instantly recognize and quickly react to urgent or emergency situations, so it is necessary that the pilots be aware of the threats that face them at various stages of flight. In civil aviation, no flight surgeon checks out each pilot before each flight. There is generally no one who acts as a supervisor to check-out the pilot before the planned flight. In fact, there is often very little planning taking place before most flights in privately owned or rented, civil aviation aircraft. Consequently, it becomes increasingly more important that civil aviators know the physiological consequences of the actions that they may take, and act accordingly.

TEACHING MATERIALS

The University Aviation Association recently took a survey of its members to determine which textbooks are being used for the courses that their member colleges and universities teach. No information was available concerning how many schools actually teach aviation physiology as a separate course. Only three universities indicated that they use a textbook. One of them used the USAF pamphlet on Physiological Training, and two used local texts. "Local texts" is a euphemism for a locally-prepared handout.

Only one institution in the entire United States, the University of North Dakota, has an altitude chamber for human aviation training. The courses offered include one for commercial aviators, senior training personnel, and flight attendants who have not ever participated in an aerospace physiology course or an altitude chamber flight. It consists of 18 hours of classroom instruction over a three-day period and includes two chamber "flights." Another course involves regional and corporate pilots and flight attendants who have never participated in an aerospace physiology course or altitude chamber flight. It consists of 13 hours of classroom instruction with two chamber flights and is a two-day program. The third program involves general aviation pilots and helicopter aviation initial training. The classroom instruction is covered in six hours and is completed in one day. A similar program for corporate and commercial recurrency is available for pilots who have completed FAA or military aerospace physiology training within the past five years. They receive five hours of instruction in the classroom and a hypoxia demonstration flight in the altitude chamber. Since no suitable textbook can be found for these classes, the instructor relies upon handouts that he has authored.

The Ohio State University Aviation Department offers a three quarter-hour credit course entitled AVN 414, Flight Physiology. The objectives of the course are to develop a knowledge and awareness of the mechanics of the human body as related to the atmosphere on earth and in flight, to understand the effects of altitude, lowered atmospheric pressure, stress, drugs and alcohol, "G" forces, and other phenomenon the body will encounter in flight, and to understand the types and use of protective equipment, survival equipment and techniques, and to relate them to practical situations. The text used is *Physiological Aspects of Flight* written by Dr. Robert J. Del Vecchio, Ph.D. and handouts developed by the professor. The book is only partially oriented to the pilot and deals in technical detail which is generally unimportant to the average general aviation pilot. Since the University lacks proper facilities, no altitude chamber flight is offered; however, participation in an altitude chamber flight sponsored by the FAA at nearby Wright Patterson Air Force Base is greatly encouraged.

Middle Tennessee State University was another school that responded to the University Aviation Association survey. They use a locally-formulated text.

AIRLINE TRAINING

Typically, the airlines, when training their pilots either as new hires or for recurrent training do not address physiological problems. For most airlines, pilots who come to their "schoolhouse" are expected to be fully qualified for flight. The basic assumption is that they have received all of the training necessary to make them safe, efficient pilots who only need to be trained in the type of equipment to which they are to be assigned. The training they receive depends upon the type of equipment they will be flying and is basically composed of aircraft systems such as hydraulic, electrical, pneumatic, pressurization, heating and cooling, and other mechanical systems.

At USAir, an official noted that for initial training (new hires) approximately 65% of the class time was devoted to systems and the remaining 35% was devoted to FAA-mandated training which includes security, defense against hijacking and other related subjects. A query to an American Airlines pilot brought the response, "Nothing. I don't remember being taught anything about physiological subjects during my training at American." Later queries to American revealed that civilian-trained pilots are shown a video tape on physiological training. The pilot went on to indicate that the emergency masks were ill-fitting and often dirty. The one-size-fits-all concept was not optimum in that pilot's mind and it was further stated that each pilot should have their own insert for the quick-don mask to encourage inspection before flight and to take away the stigma of inhaling someone else's germs.

UNITED STATES AIR FORCE TRAINING

The United States Air Force operates the School of Aviation Medicine at Brooks Air Force Base near San Antonio, Texas. That this school came into existence at all significantly bears on the problem this paper addresses. The development of aviation medicine took place in part because of the appalling death rate among flying cadets during the First World War. In fact, during WW-I, most air fatalities were not due to enemy action. Consequently, the first Chief Surgeon of the Aviation Section of the Signal Corps, U. S. Army, one Lt Col Theodore Charles Lyster, recommended that a research board be established to investigate all of the conditions that affected the physical efficiency of pilots, to carry out tests and experiments and to "provide suitable apparatus for the supply of oxygen." A research laboratory was established and it gradually became a training academy for flight surgeons. By 1922, it had become the School of Aviation Medicine.

The School of Aviation Medicine was originally intended to be a place where pure research programs on the effects of flying at altitude were to be carried out. In fact, in the beginning, Dr. Lyster and his associates were charged only with examining pilot recruits. Lyster had more in mind than examining centers. He wanted to establish a semi-independent medical service, modeled after the British "Care of the Flyer" service with specially-trained doctors attached to flying units in the field. They were to go beyond the basic conditions of the pilot's health to discover the conditions that had influence over the capabilities of the persons who were flying.

A Medical Research Board was established on October 18, 1917. They were to report to Colonel Lyster who had been appointed as Chief Surgeon of the Aviation Section, Army Signal Corps a little over a month earlier. Their charter included the power:

1. To investigate all conditions which affect the efficiency of pilots.

2. To institute and carry out, at flying schools or elsewhere, such experiments and tests as will determine the ability of pilots to fly in high altitudes.

3. To carry out experiments and tests, at flying schools or elsewhere, to provide suitable apparatus for the supply of oxygen to pilots in high altitudes.

4. To act as a standing Medical Board for the consideration of all matters relating to the physical fitness of pilots.

In short, the Board was to establish the practice of Aviation Medicine (Although that description was to come much later) and to do all such things as might affect the pilot's health and safety.

In the book, *50 Years of Aerospace Medicine*, by Green Peyton, (page 10) the board had already come to some significant conclusions about the forces and effects that flying had on the human body. Speed, "G" forces, height, optical illusions, spatial disorientation, turbulence, and the effects of atmospheric pressure on the body all played a part, but to them, the problem of insufficient oxygen at high altitudes was the single most important problem to solve.

If one looks at the current United States Air Force curriculum for physiological training, it is easy to tell that these conclusions are the basis for that curriculum and that with some minor exceptions, very little has changed over the years. Oxygen deficiency, with its attendant confusion or loss of consciousness, was believed to be responsible for many otherwise unexplained accidents in flying. The obvious remedy then, as it is now, is to determine the progressive effects of oxygen starvation and to train and equip the pilots to overcome them. The problem was that equipment for overcoming the problems had not yet been developed.

As a former jet fighter pilot, this writer has been involved in the use of life support equipment for a considerable length of time. The inspection, checking, and proper wear of that equipment became second nature as a result of continuous training afforded by the Air Force. Because of that ingrained respect for the use of the equipment and that second-nature habit of wearing and using it properly, I suffered no physiological effects from a surprisingly violent incident. I was instructing from the back seat of a 2-seat F-100F jet fighter when at 28,000 feet, the entire canopy completely and explosively separated from the aircraft. The gasses inside our bodies expanded approximately five times their original volume in less than a second. We were fortunate to be below 50,000 feet altitude where this event would have been non-survivable. We were subjected to the extreme cold temperatures of high altitude, and were also subjected to violent buffeting, turbulence, and gyrations of the aircraft.

Because I had my equipment on tightly and securely, had taken the precaution to pre-breath 100% oxygen for 30 minutes prior to the incident, and had not removed my mask thereafter, I suffered no ill-effects of nitrogen-induced bends, chokes or any symptoms of hypoxia. I was therefore able to remain in control the aircraft, rationally think of our alternatives, make appropriate decisions and get us safely on the ground at Wright-Patterson AFB, where a recompression chamber would have been available had we needed it.

It is significant to note that although a great deal of progress has been made in aviation technology, that is, the ability of general aviation aircraft to fly higher and faster, and a great deal of advancement has been made in the equipment that helps people to survive and work at higher and higher altitudes, no change has been made either in the physiological makeup of the individual, or in the environment in which an individual pilot or crew member must operate.

The conclusion then is that if the problem of oxygen deprivation was discovered in the early 1900s by the military, when their aircraft were generally only capable of flying where civil airplanes now fly, it is equally important now that civil aviation officials take the same course of action as was done back then and take steps to protect and educate the pilots of today.

THE NEED FOR TRAINING

In this writer's opinion, **every pilot needs some physiological training.** The <u>extent</u> of that training should be dependent upon the type of equipment that the individual will be flying, that is, whether the machine is capable of taking the pilot and passengers to altitudes into the upper reaches or above the physiological zone. In order to understand this concept it is important to know what can happen to the body at certain levels.

The FAA has divided the atmosphere into physiological divisions. The lower division is known as the Physiological Zone and generally goes from sea level to about 12,000 feet. The next zone is from 12,000 feet to about 50,000 feet and is known as the Physiological Deficient Zone. Above that is the Partial Space Equivalent Zone and the Total Space Equivalent Zone. The latter two are not relevant to this discussion.

In the physiological zone, the body is more or less adapted. Humans can experience middle ear or trapped gas difficulties, shortness of breath, dizziness, or headaches with prolonged exposure or exertion. The zone can become dangerous if a pilot chooses to fly when ill, fatigued, under the influence of alcohol or drugs, smoking heavily, or under stress. Significant degradation in performance is possible after long exposure to the upper reaches of this zone and when under the influence of one or more of the above factors.

It is in the physiological deficient zone that most of the troubles due to oxygen deprivation occur. The effects of illness, drug and alcohol abuse, hangover, smoking, fatigue and stress are much more pronounced. The effects may be insidious and the onset of effects hardly known to one who is not trained and has not experienced them in controlled situations. **It is this last situation that inclines me to believe that some form of physiological training must be required for all pilots during their initial training.** As I teach physiological training to my college students, discuss the subject in informal sessions, and speak to groups of aviation enthusiasts, I find an amazing lack of understanding on the subject. Most comments are of the "Gee, I never knew that could happen to me." type. Some even relate one or more incidents that had puzzled them during a flight that were explained when they learned more about flight physiology.

As a result of my flight physiology classes, many young aspiring pilots have applied for the altitude chamber sessions at nearby Wright-Patterson Air Force Base or at the FAA facility at Oklahoma City. Comments from students returning from the training are always positive and express how much they were able to relate to the academics that were taught in our classes. In fact, most comment that the half-day of academics offered before the chamber ride should be used as a refresher because the subject is too broad for a beginner to learn in a session that short.

The need for exposure to the altitude chamber for pilots who have a very small chance to exceed the physiological zone is problematical. In lieu of that exposure,

> I would recommend a very thorough academic indoctrination concerning physiological problems that relate to performance decrement when altitude is combined with stress, age, sleep deprivation, fatigue, alcohol, drug use, (either prescribed or non-prescription) and smoking. Emphasis should also be placed on proper diet, nutrition and physical conditioning.

Many pilots do not know the effects that poor nutrition or physical conditioning can have on the body. I would in particular recommend that each person who wishes to become a commercial pilot or an airline transport pilot be exposed to a formal course of study on flight physiology and take a "flight" in the altitude chamber if they will fly aircraft capable of sustained flight above the physiological zone. Private pilots, in my opinion, need only to be exposed to the altitude chamber when they plan to upgrade to an aircraft that is capable of flying above the physiological zone.

Persons wishing to become flight instructors should also be exposed to the altitude chamber. The reason why I believe that flight instructors must be exposed to significant training and an altitude chamber "flight" is that they are often the first exposure to aviation that a non-flyer encounters. They are often the last instructor that the newly-licensed pilot will encounter between the practical flight test and the next bi-annual review. Since the bi-annual review is so nonstructured, it is likely that the instructor giving the check will not take the time to include physiological factors in the review, especially if the instructors are ignorant of the effects themselves. Consequently, the private pilot has no recurring exposure to the physiological problems and dangers posed when they leave the ground. If the emphasis were placed on physiological training in order to qualify for the commercial or instructor ratings, those instructors would be more likely to emphasize that subject during their reviews. The solution is to require certain items to be covered during the basic course of instruction and at every bi-annual review and to make physiological factors, relative to the performance of the aircraft to be flown, one of those required items.

General aviation pilots who will operate aircraft capable of flying above the physiological zone, (12,000 feet) should be required to undergo physiological training which includes a chamber flight for their initial certification. My recommendation for recurring training would include a refresher such as is given at Oklahoma City or at any cooperating Air Force or Navy Base or NASA facility. In the event the chamber training is not possible or available, instruction from a prescribed syllabus (which will be detailed later in this paper) could be given by a qualified instructor and a check flight in an aircraft capable of flying above 25,000 feet could be substituted. This check ride should include a hypoxia demonstration which would, in an unpressurized aircraft, include removing the mask and observing the symptoms.

In a pressurized aircraft, the pressurization should be gradually released so that the insidious nature of hypoxia is demonstrated. The flight instructor or examiner would remain on oxygen at all times. Flight instructors/examiners would have to be especially certified to perform this hypoxia demonstration and would have to be in complete control of the aircraft. An additional observer would have to be on board to place the mask on the individual in case they were unable to do so for themselves.

RECURRING TRAINING RECOMMENDATIONS

This recurring training should take place every five years as long as the pilot is flying high-altitude-capable aircraft. There are several reasons for this recommendation. First of all, an individual's symptoms of hypoxia generally remain the same for lengthy periods of time; however, some symptoms are dominant and others occur with longer exposure. The dominance of symptoms changes over time. Where one individual may begin to have "tunnel vision" as the first symptom early in life, the first symptom may become tingling, and hot and cold flashes later in life. The need for constant monitoring of one's symptoms is apparent.

The Director of Aerospace Physiology at the University of North Dakota, Mr. David B. Blumkin is a Board Certified aviation physiologist and has spent 20 years in the United States Air Force as an Aviation Physiologist. He recommends recurring training every five years.

The current Air Force regulation calls for recurring training to be required at three-year intervals. As more experience is being compiled, and budgets are being squeezed, the School of Aviation Medicine will be recommending a five-year interval between recurring training sessions.

THE CORE CURRICULUM

As has been previously stated, the core curriculum for pilots who will not fly aircraft capable of rising above 12,000 feet would be less stringent than those who will fly higher performance aircraft. The following topics should be considered the minimum necessary to be aware of the dangers of flight in the physiological zone.

1. The Physics of the Atmosphere:

   Introduce the Physiological Zones:

   Physiological Zone, Physiological Deficient Zone, Partial Space Equivalent Zone, Total Space Equivalent Zone.

   The Gas Laws:

   Graham's Law which explains the transfer of oxygen into and carbon dioxide and other gasses out of the body; Boyle's Law, which explains the expansions of trapped gasses, middle ear and tooth pains while climbing or descending; Henry's Law which explains "evolved gasses" which in turn are the cause of the bends; Charles' law, explaining the effects of pressure changes with temperature, and Dalton's Law, which explains altitude sickness (hypoxic hypoxia).

2. Knowledge of Bodily Functions:

   In order to understand the affects of these laws on the body, some knowledge of the working of the body itself must be known. Respiration, both internal and external should be examined. The role that circulation plays in the onset of hypoxia is important. This would lead to a study of the types of hypoxia, the methods of combatting each type, and the requirements for supplemental oxygen. Since symptoms can be similar, hyperventilation recognition and treatment should also be emphasized in this phase of training.

3. Decompression Sickness:

   The effects of trapped and evolved gasses on the organs of the body and their effect on pilot performance should be taught. The sinuses, teeth, joints, blood stream, and sense organs are affected by decompression sickness and those altered states should be thoroughly examined and explained. The effects of hypoxia on vision, especially night vision are important to the pilot and should be understood.

4. Oxygen Equipment:

   Pilots should know about the types of oxygen equipment that are required for different situations in flight. A familiarization with regulators and masks, equipment checks, and other general rules is very important. They should also have an understanding and appreciation for the dangers of storage and use of oxygen. Some study on the dangers of toxic gasses and vapors, their symptoms and the emergency actions that need to be taken when those symptoms are detected is also important.

5. Drugs, Alcohol and Medication:

   The effects of drugs, both prescription and non-prescription, are not well known in the general aviation community especially when related to flying even in the lower reaches of the physiological zone. Some study should be related to the kinds of drugs and medications that can be safely used by the pilot. Often, pilots self-medicate or do not see a flight-qualified physician for fear of grounding. Some medications have been proved to be safe for flight and those should be known to the flier. The dangers of combining two different prescriptions should also be emphasized.

SUBJECTS TO BE TAUGHT IN ADDITION TO THOSE DIRECTLY RELATED TO ALTITUDE

1. The Effects of Stress:

   All pilots should have an appreciation for the effects of stress whether it is self-imposed by the use of illicit drugs or alcohol or externally-imposed by associates, family members, financial difficulties, and other causes. Stress can significantly lower job performance, memory, concentration, and situational awareness. Pilots should be aware of and make allowances for lowered performance.

2. Spatial Disorientation:

   The problems of spatial disorientation reach far beyond those encountered during instrument flight. In fact, many fatal accidents have been attributed to "pilot's loss of control" when visual references have been lost. Being aware of the problem and taking corrective action such as a 180-degree turn for a non-instrumented pilot should be taught.

3. Aging:

   The problems of aging on eyesight, night vision adaptability, loss of hearing, vision, muscular coordination, and other factors should be taught. Older pilots can be capable of many years of flying if they often and faithfully check themselves out for deterioration of skills, learn new material and techniques, and carefully monitor their performance. They should also be checked by and consult an Aviation Medical Examiner (AME) when in doubt about their capabilities. The time to quit flying voluntarily should be one topic of discussion.

EXPANSION OF THE CORE CURRICULUM

For those crewmembers who will be flying in the physiological deficient zone, additional problems can be encountered and training should be enhanced to be able to cope with those problems. Although it is not a stated requirement, an instrument rating is a practical necessity when flying high performance aircraft at or above 18,000 feet. The stresses of flying under instrument conditions can cause the body to use oxygen at a higher rate.

1. Time of Useful Consciousness (TUC):

   Stress the rapidity of onset of hypoxia when rapid or explosive decompression takes place. Teach the causes and problems of shortened TUC and the ways pilots may be prepared to deal with them.

   It is in this regime that physiological problems take place rapidly. In fact, at around 20,000 feet, the Time of Useful Consciousness (TUC) is approximately 30 minutes. The TUC shortens as altitude is increased; for instance, at 25,000 feet, the TUC is reduced to three to five minutes. Time of Useful Consciousness is defined as that length of time within which an individual is able to effectively or adequately perform flight duties with an insufficient supply of oxygen.

   Factors affecting those times include the rate of ascent, with the more rapid the ascent the shorter the TUC becomes. The most dangerous form of ascent occurs when a rapid decompression takes place. In a pressurized aircraft, the loss of a window, or door, or some similar large portion of the pressure vessel causes the occupants to be raised from a nominal pressure altitude inside the cabin of 6,000 to 8,000 feet to actual flight altitude in a few seconds. Typically, if the aircraft is flying above 25,000 feet, this can cut down the TUC to somewhere between 30 and 60 seconds. Physical activity and day-to-day factors such as diet, rest, drugs, smoking, and illness also tend to shorten TUC. Pilots flying aircraft capable of reaching critical altitudes must be made aware of these factors.

2. Survival and Post-Crash Actions:

   Aids to survival including care and testing of emergency locator beacons, first aid kits, basic survival equipment, and terrain-specific equipment should become familiar to the pilot. Pilots should know basic first aid, evacuation techniques, signalling, radio techniques, and self-help ideas.

   Some study of the actions that must be taken in order to survive in a post-crash situation would be highly recommended although not mandatory. The subject matter should be slanted toward the type of equipment that the pilots would be flying. In case of a pilot flying a personal aircraft with few passengers, small-scale escape and evacuation, post-crash trauma, first aid, and all-terrain, all-weather survival techniques should be subjects of the course.

   With larger aircraft such as airliners, emergency evacuation, fire and smoke disorientation, passenger safety and survival, and other factors relating to the carriage of large numbers of people should be taught. Overwater techniques, ditching, and survival at sea are additional subjects for recurring training.

RECOMMENDATIONS

Basic recommendations have already been made and justified in various sections of this paper. However, what has not been directly addressed is whether flight physiology training should differ for general aviation, corporate, or airline pilots or should it be addressed only on the basis of the type of aircraft flown.

- It is my recommendation that the basic core curriculum be the same for <u>all</u> pilots regardless of their ratings or the type of equipment they are flying.

  The effects of lack of oxygen are insidious whether it is caused by unprotected high-altitude flying, or by carbon monoxide from a leaking exhaust system. Either condition can lead to the same result. When an untrained pilot encounters these symptoms, which often appear to be similar, they may not be recognized, therefore, no corrective action may take place. Pilots must know the limitations of their bodies and know how to cope with oxygen deprivation situations.

- All pilots should receive a thorough academic indoctrination concerning physiological problems that relate to reductions in performance with the onset of a hypoxic condition.

- All pilots should receive training about factors that produce performance decrements such as stress, sleep deprivation, fatigue, alcohol and drug use. Smoking, diet, and aging should be a part of the course. Recognition of those symptoms, and the corrective actions that must be taken should be a centerpoint in the course.

  Performance degradation, and the attendant problems related to it while flying even a low-performance aircraft can lead to a fatality. NTSB reports show where pilots have lost control of the aircraft during all phases of flight for no apparent reason. Toxicological reports range from drugs and alcohol to carbon monoxide poisoning. With education, pilots would be more inclined to take their physical condition into consideration during the pre-flight phase of the mission.

- **Any person who is to fly any aircraft capable of operating in the Physiological Deficient Zone or above should be required to take a full physiological training course including the altitude chamber "flight" and to continue to receive recurrent training at least once every five years.**

  Aircraft in common corporate use today often exceed 40,000 feet and many, including the latest Learjets, are certified for flight above 50,000 feet. In order to maintain an adequate cabin pressure altitude, the pressure differential, that is the difference between the pressure of the air compressed within the pressure vessel of an aircraft and the outside air, is approaching 10 pounds per square inch (psi). Non-survivable decompression is defined as one in which the pressure differential loss of 10 psi occurs within one second. At that rate, the alveoli (small sacs within the lungs that transfer oxygen to the blood and carbon dioxide from the blood) will rupture. Survival is impossible once this occurs.

The supersonic Concorde uses a 10 psi differential but it has a door of the inverted plug type which is impossible to open under pressure and more importantly, it has very small windows and a large supply of pressurization air. Small corporate aircraft have bigger windows, a smaller cabin space and lower pressure flows. Private aircraft such as the Cessna P-210 have even larger windows, an even smaller cabin area and a low flow pressurization system. Although they generally fly at far lower pressure differentials, the rapidity of decompression could easily be less than one second.

- All pilots should receive training and be able to recognize that adequate nutrition and good physical conditioning also play a significant part in the pilot's capability to fly safely.

  In my experience as a professor of aviation physiology teaching students who hold ratings up to and including the Airline Transport Pilot rating, an alarming lack of appreciation for the effects of hypoglycemia, or low blood sugar is exhibited. Symptoms can be very similar to hypoxia but cannot be cured by supplemental oxygen. Symptoms are aggravated by flying at higher altitudes and under stress situations. Prevention is therefore the best cure. Only through participation in course work that stresses these points can accidents caused by this condition be remedied.

  Beyond that, however, additional items and whether or not an altitude chamber flight would be required would depend upon what the capabilities are of the aircraft that the pilot would be flying.

- Recommend that items beyond the core curriculum for instrument-rated pilots flying aircraft capable of blind flight would cover spatial disorientation, visual illusions, and false sensations. Pilots should experience disorientation in the Barany Chair, the Vertigon or the Vertifuge wherever possible.

  One exception to the equipment hypothesis would be the proposed requirement that all flight instructors be required to take the full academic and chamber flight curriculum. The purpose of this action is to make flight instructors intimately familiar with the hazards of flight into physiologically-dangerous regimes and to have them be knowledgeable in passing along this information to their students. Since students and private pilots are capable of blundering into dangerous physiological situations, the trained instructor can alert them to the hazards and warn them, with some authority, not to venture into that realm.

- Recommend that commercial pilots and airline transport pilots be required to take the full course including the altitude chamber, the Barany chair, and rapid decompression.

  The recommendation that commercial pilots and airline transport pilots be required to take the full course including the altitude chamber is that they will most likely be called upon to fly higher performance aircraft capable of reaching dangerous altitudes. If they are not assigned to fly aircraft capable of reaching critical altitudes, altitude chamber training should be made optional. Commercial pilots and airline transport pilots will also be responsible for the lives of other persons who pay for their flights and who depend upon them to care for their well-being in flight.

COMMENT

It is a well-publicized fact in the aviation community that eight out of ten accidents involving fatalities are caused by pilot factors or operator error. At this writing, accurate statistics are not available detailing how many of those operator error accidents can be attributed to physiological causes. However, in discussing the subject with individuals in the National Transportation Safety Board, the Department of Transportation, and the United States Air Force, it becomes apparent that significant amounts of accidents occurred with physiological or psychological factors as either the primary or a contributing cause.

It is also a well-known fact in the aviation community that timely, accurate, and recurrent training is the best method available to prevent mishaps. Another well-known fact is that usually, training is not mandated until some significant accident has occurred to shock regulatory agencies into action. This is one significant area where a precedent has already been set by aviation authorities in the military services. Over the past two decades, military accidents as a function of flying hours (with one year as a notable exception) has continued to decline. Training of pilots has intensified during those years in all phases of flight as money to do so has been made available in significant amounts.

According to officials of the School of Aviation Medicine, only one accident in the history of the Air Force has ever been attributed to the use of drugs. Of course, service pilots are admittedly the cream of the crop, with a great deal of elimination taking place throughout the training environment. However, as one doctor noted in an interview, "We still represent the population of the United States and we still will have some pilot who will use drugs." Training and the threat of enforcement has kept that usage to a manageable minimum.

The private sector cannot hope to duplicate that record but by addressing the problems of physiological training before serious accidents begin to occur, by implementing adequate training programs, and by anticipating those training needs, physiologically-related accidents can be eliminated before they happen.

CONCLUSION

In this expert opinion paper, I have provided a few suggestions for curriculum and training needs. I have also attempted to provide justification for each of those ideas. The task does not end here. It is now the job of the regulators and policymakers to take these suggestions and mold them into effective additions to the Federal Aviation Regulations so that people in the field can implement them. It will take the cooperation of all of the segments of aviation acting in concert to provide the industry with the numbers of safe, intelligent, trained, and experienced pilots that will be needed in the next decade. I hope that my part is significant in this endeavor.

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APPENDIX B

SUMMARY OF ASRS REPORTS

29778 — **The aircraft sustained a loss of pressurization.** The cabin altitude climbed to 20,000 feet. The crew followed all emergency procedures. The flight attendants were cited by the reporter for doing a good job. This report had many indications of good crew coordination and flight attendant training in these procedures.

30052 — **The aircraft experienced a cabin pressure rise to about 13,500 feet, while in cruise at FL350.** The passenger O_2 masks deployed and an emergency descent was made. Control of cabin pressurization was regained and, after a fuel check, the flight climbed back to FL310 and continued to their destination. Since the masks had already deployed they were no longer available with automatic presentation. The Minimum Equipment List (MEL) usually states that passenger O_2 masks must be available for automatic presentation above a specified altitude, such as FL250. This is probably a case of noncompliance with FAR 91.30.

30118 — **The aircraft had to be depressurized manually.** During this process the crew was distracted and lined up for approach to a runway at a nearby military base. The mistake was noticed and a side-step approach was made to the correct destination.

30524 — **One of the involved aircraft had lost pressurization and was holding.** A second aircraft departed a nearby, busy airport and, due to a trainee controller, was cleared through the altitude of the holding aircraft. The trainee was being monitored by a recently-certified controller. The shift supervisor caught the error and corrected it with vectors and altitude changes before any conflict could arise.

30535 — **The aircraft had a touchy pressurization system which the First Officer (F/O) was trying to handle.** During the descent the crew got behind the checklist and the Captain descended below their cleared altitude with opposite direction, conflicting traffic. (The aircraft does not have an altitude reminder.)

30855 — **The aircraft suffered a loss of pressurization at FL270.** The crew had experienced problems with the pressurization controller on three previous legs. The FAA jumpseat rider violated the crew for improper use of their oxygen masks. FAR 121.329 (b) (1) specifies: "at cabin pressure altitudes above 10,000 feet, up to and including 12,000 feet, oxygen must be provided for and used by each member of the flight crew on flight deck duty, and must be provided for other crewmembers, for that part of the flight at those altitudes that is of more than 30 minutes duration." The flight deck crew donned their O_2 masks when the cabin altitude (as opposed to aircraft altitude) went above 12,000 feet, and after 30 minutes. This is another example of non-compliance with the FARs.

31372 — **The aircraft overshot assigned altitude during climb.** The F/O was attempting to adjust the pressurization while the Captain was adjusting the fuel flows. The reporter (Captain) stated that he wasn't sure who was flying the aircraft.

31716 — **While in cruise at FL370, the aircraft sustained a rapid loss of pressurization which the crew was unable to control manually.** The crew made an emergency descent. During the incident, some passengers and a flight attendant received injuries. The crew elected to land short of their destination for medical attention.

31745 — **This aircraft was in descent through FL350, over mountainous terrain, and sustained either a static discharge or a lightning strike.** As a result, their glass cockpit instruments went haywire, with all alarm signals sounding, and the system went to standby power. From what instruments they could occasionally read (the instrumentation was intermittent), they lost both engines and the cabin pressure. They declared an emergency and attempted restarts. Both initial restarts overtemped the engines and the crew shut them down. On subsequent restarts they eventually got both engines running again at about 12,000 feet and made a high, fast approach to the airport. (During all this a passenger threatened a flight attendant and the crew had security meet the aircraft at the gate.)

31958 — **This aircraft sustained a loss of pressurization while in cruise at FL350.** The crew made an emergency descent and landed short of their destination.

32363 — **During cruise, at FL370, this aircraft lost its right air conditioning pack.** The Captain descended to FL250, the single pack altitude for the aircraft. The crew contacted maintenance and, while performing the recommended procedure, lost the left pack. The aircraft depressurized, the passenger O_2 masks deployed, and the crew made an emergency descent to 13,000 feet. While at that altitude, the Flight Engineer (F/E) was able to get the packs to operate again and they continued to their destination.

32473 — **In cruise, at FL370, the pressure control "Auto Fail" light came on and the system shifted to standby.** Cabin pressure continued to climb and the passenger O_2 masks deployed. The crew attempted to reach ATC to declare their emergency descent, were unable to, and squawked "7700" (the emergency transponder code) while making an emergency descent. At 16,000 feet they regained control of the pressurization, reestablished contact with ATC, and continued to their destination.

32476 — **During climb, at FL330, aircraft pressurization became unmanageable and the crew made an emergency descent.** The F/E had set the pressurization system improperly, and at power reduction for the emergency descent, the cabin altitude ran away and descended at 2,000 feet per minute (fpm) from a cabin altitude of 12,000 feet + to sea level. A number of passengers complained of ear pain. The reporter felt the F/E (a recycled pilot over 60 years of age) was incompetent and should not be flying.

32827 — **The Captain of this flight was flying while suffering from fatigue and recovering from viral pneumonia and, as a result, made a number of errors.** Navigation errors were made as well as improper checking of the maintenance log for needed repairs that were not performed. The overlooking of undone maintenance items created more problems for the crew on their return flight. The Captain was flying when he should not have been because of fear of repercussions from the company.

33149 — **This crew did not make their assigned crossing restriction on the arrival route.** The problems leading up to this included fluctuating cabin pressure, emergency lights blinking on and off, the stall warning sounding for protracted intervals, and a cross-tie lockout. The crew was distracted and the F/O was writing up the maintenance log at a time when he should have been monitoring the aircraft. This was because of a short turnaround time on the ground for their next flight.

33192 — **On climbout from Newark through FL240, the crew experienced rapid loss of cabin pressure.** They tried all the recommended procedures to control cabin pressure manually, then requested and made emergency descent, and followed emergency procedures.

33550 — **During climbout the crew experienced pressurization problems, got distracted, and overshot the assigned altitude.** They corrected the problems and continued the flight.

33816 — **Shortly after takeoff, the crew noticed that the aircraft was not pressurizing and the cabin altitude was rising with the aircraft.** They were experiencing surging of the number 3 engine and had an open door annunciator light. The crew shut down the engine, dumped fuel, and returned to correct the problem.

33970 — **While the aircraft was cruising at FL330, the crew noticed a slow rise in cabin altitude.** They were unable to control it manually, requested a descent, and received a descent clearance to FL290. They had intermittent communications with ATC, declared an emergency, and conducted an emergency descent. At 16,500 feet they regained control of cabin altitude and radio contact with ATC. The flight landed short of its destination.

34227 — **The aircraft cabin altitude was not descending at the proper rate and the crew was distracted by the pressurization problem.** As a result of the distraction, the crew missed radio transmissions from ATC and didn't descend at the proper time.

34916 — **The aircraft had a loud air leak around the Captain's side window and the crew was unable to control cabin altitude.** They initiated an emergency descent and landed short of their destination. The aircraft was ferried unpressurized to a maintenance base where it was found to have the pressure-sensing hoses behind the F/E panel hooked up backwards, causing a pressurization leak at one of the outflow valves.

35030 — **On descent into Houston, at FL360, both air conditioning packs shut down and an emergency descent was begun.** At FL240 both packs came back on the line and a normal descent was continued into Houston. The problem was diagnosed as overheated packs shutting down automatically. After they had cooled off, they came back on the line automatically.

35417 — **On climbout, this crew had no control over pressurization and requested a return to the airport.** During the approach, with the Captain and the F/E troubleshooting the problem, the flying pilot allowed his mind to wander and undershot his assigned altitude. Fortunately there was no traffic conflict and they were cleared to continue approach and land.

35579 — **The aircraft sustained an explosive decompression due to the loss of the First Officer's (F/O) side window at FL230.** The F/O received minor injury, and 1/2 of his O_2 mask was ripped away and unusable. The Captain made an emergency descent with the F/O doing the checklists, but the Captain did not use his O_2 mask at all. This shows a lack of training in, and understanding of, the effects of unpressurized flight without oxygen, since the usual reaction to such a pressurization loss is to don the O_2 mask.

35883 — **At FL200 this aircraft sustained a rapid loss of pressurization, the crew made an emergency descent, and landed short of their destination.**

35901 — **This aircraft was unable to pressurize the cabin with the engine driven blower.** The crew had been pressurizing with power from the auxiliary power unit (APU) to get maximum cooling power for the cabin. At this time other equipment problems occurred with hydraulics and fuel crossfeeding. The crew requested priority handling, descended, and discontinued cabin pressurization with the APU. They were able to handle their other problems and continued to their nearby destination with priority handling.

36048 — **While the aircraft was climbing through FL210, the cabin altitude exceeded 10,000 feet and the cabin altitude warning horn sounded.** The crew donned their O_2 masks and attempted all recommended procedures to control the cabin altitude (e.g., selected standby; selected manual control; closed the outflow valve). They were unable to regain control, made an emergency descent, and returned to the point of departure. They made all prescribed contact with ATC and followed company-operating procedures for the emergency.

36950 — **The flight continued to its destination after an emergency descent, during which passenger O_2 masks were deployed.** At one point during the balance of the trip, flight was conducted at FL270. The Minimum Equipment List (MEL) for the airplane specified no flight above FL250 without the availability of automatic presentation of passenger O_2 masks. The masks could not be presented automatically because they had been deployed in the previous emergency descent. This involves noncompliance with FAR 91.30, regarding Minimum Equipment Lists, and a lack of knowledge of MEL requirements.

36895 — **This military transport had a swelling of a high pressure hydraulic line in the cabin with subsequent leaking.** Rather than burst the hose and have the fluid spray throughout the cabin, with potential toxic effects on passengers, the crew isolated the system. While dealing with the problem, the crew was distracted and overshot their assigned altitude by more than 1,000 feet. Since the flight was near its destination, the crew continued at low altitude without further problems.

37284 — **Because of distraction discussing a prior pressurization problem, the crew of this aircraft was inattentive and missed an assigned crossing altitude.** No comment was made by ATC and no further problems ensued.

37289 — **The crew experienced a pressure controller malfunction and were unable to control the cabin pressure.** They asked for and received a descent clearance. At FL180 they regained control of the cabin pressure and continued to their destination at that altitude.

37351 — **This aircraft overshot its assigned altitude in climb because the crew was distracted by manually controlling the pressurization.** The aircraft is a commuter in service in a high ambient temperature area, with many legs per day. Since the pressurization does not provide adequate cooling automatically, the crews attempt to do it manually. The body stresses incurred in eight pressurization cycles in a very hot environment are reported as very wearing. The crew, in attempting to alleviate passenger complaints and increase the comfort level, was distracted and overshot the altitude.

38010 — **Crew fatigue and aircraft mechanical problems led to the crew flying the wrong departure headings.** The crew had flown an average of 110 hours in each of the prior five months. Shortly after takeoff, the pressurization and the Captain's intercom failed. In addition, the location of the aircraft was a known area of radio reception difficulties with the tower. All of the above and a misunderstanding on the part of the flying pilot led to the navigational error. FAR 121.471 (a) (2) allows Part 121 crews to fly 100 hours maximum per month; FAR 135.265 (a) (2) allows Part 135 crews to fly 120 hours maximum per month. From the author's experience as an airline pilot, 120 hours of actual flying in one month, combined with the additional duty time required to produce those 120 hours, leads to crews fatigued to the point where they start making mistakes. This, combined with airlines which schedule minimum legal layovers for rest, and consecutive multiple leg days (sometimes 4 to 6 in a row) leads one to believe that FAR 135.265 hours should be revised downward in the interest of safety.

38565 — **Crew missed the crossing altitude for the STAR they were assigned.** The F/O (pilot flying) had been trying to control the pressurization while the Captain was working the radio to get the ATIS and gate assignment. Nobody was minding the store.

38570 — **Shortly after takeoff a rear boarding door came open and the integral stairs deployed.** The flight crew experienced no control problems and returned to land. One of the flight attendants in the rear unfastened his seat belt and went to the open door to check it out, although his emergency training and common sense should have made him aware that was a life-threatening move. The flight had just begun to pressurize, so the decompression was minor, or much worse could have happened.

39749 — **The aircraft descended through the assigned altitude as a result of crew distraction due to pressurization problems.** The entire flight had been made partially pressurized, at 10,000 feet, due to a tear in the fuselage. The F/E was busy trying to coordinate the pressurization and power application with the F/O, who was flying. One item on the "DESCENT" checklist required a dual response from both pilots and their attention to a bug setting. At this point the pilots' concentration was shifted and the overshoot occurred.

40389 — **An altitude overshoot occurred as the crew was trying to reset an inoperative cabin pressure controller.** The problem was compounded by the fact that the autopilot was set for altitude capture and level-off and did not capture. The crew was busy working with the pressurization and didn't monitor the aircraft progress closely enough.

40406 — **The pressurization was erratic in descent, occupying the F/E; the Capt. and F/O were busy interpreting radar echoes and avoiding heavy cells; and, the aircraft overshot the assigned altitude.** The altitude clearance was not the same as usual for that approach profile, the pilots were "programmed" to continue descent, and they flew through the assigned altitude despite the altitude alert warning.

40423 — **The crew was unable to pressurize the aircraft and elected to proceed from Dallas to Chicago at 10,000 feet unpressurized.** Because of unforecast winds, the flight arrived with 6,000 lbs. of fuel instead of the planned 9,000 lbs. and had to request priority handling from ATC.

40570 — **On departure the crew experienced problems maintaining cabin pressurization.** Attention of the crew was diverted from flying the aircraft and they overshot the assigned altitude. Pressurization was controllable and the flight was continued.

40611 — **The F/O's windshield began to disintegrate while the aircraft was at 16,000 feet on a ferry flight.** The Captain directed the crew to put on O_2 masks and goggles, depressurized the aircraft and slowed. As the windshield continued to delaminate, the Captain sent the F/O back to take a seat in the cabin, declared an emergency, and continued the approach to their destination at reduced speed, unpressurized.

40690 — **A pressurization abnormality diverted the crews attention and the aircraft descended below the assigned altitude.** The pilots were warned by the altitude alert and corrected.

41184 — **While cruising at FL350 the cabin altitude warning system activated and the aircraft depressurized.** The crew was unable to control the pressurization and made an emergency descent, continuing to their destination at low altitude. Upon examination it was found that an anti-ice duct had broken loose, creating a six-inch hole for the escape of cabin pressurized air.

41846 — **The crew leveled the aircraft at FL240 when they were unable to control cabin pressurization.** They tried all the alternate means of control unsuccessfully and requested an immediate descent. The ATC controller replied "standby," at which time the Captain declared an emergency and made an emergency descent. The aircraft returned to the point of departure.

41936 — **The crew was unable to control pressurization in descent without power on engines 1 and 3.** As a result, they were unable to make the previously issued crossing restriction. They did inform the controller and did not receive a very satisfactory answer. The reporter was writing to inform ASRS of the problem with the controller as it related to their mechanical problem.

42208 — **In cruise, at FL310, the cabin altitude horn sounded and the cabin pressure went to 10,000 feet and stayed there.** The crew was unable to control it further, requested an emergency descent and return to point of departure. At no time did the "Auto Fail" light illuminate or the system switch automatically to standby.

42890 — **Shortly after arriving at cruise altitude, the "Auto Fail" light illuminated. The crew ran the emergency checklist and made an emergency descent.** On the descent through FL200 the passenger O_2 masks deployed. The crew continued the descent and continued to their destination.

43540 — **Passing FL220 in climb the altitude warning horn sounded, emergency procedures were followed, and an emergency descent was made.** The flight continued at 10,000 feet. At the next stop, maintenance signed the item off as "fixed." Despite this, on the return trip the aircraft would not hold pressure although the cabin did not exceed 10,000 feet of cabin pressure.

43606 — **After takeoff the aircraft would not pressurize and a return was made to the point of departure.** It was found that a door seal was not seating. The door was opened and closed properly, with the seal seated, and the flight proceeded to its destination.

43996 — **After takeoff from a high altitude airport, the crew heard a loud pop followed by erratic pressurization and elected to return to land, overweight.** They did not know what caused the problem and chose to return right away rather than dump fuels first. The problem was caused by the failure of maintenance to reinstall a transponder antenna, which allowed the pressurization to escape through that hole.

45195 — **While in cruise at FL230 the crew experienced an uncontrollable loss of cabin pressure and requested an emergency descent.** On passing through FL190 the F/E regained control of the cabin pressure and the flight continued to its destination. The crew lauded ATC for their immediate response and good handling.

45648 — **While in cruise the master warning light illuminated, followed by the cabin pressure light; the crew performed the emergency checklists and made an emergency descent.** During climb, the pressurization had been erratic but controllable. A slow duct leak caused the pressure loss and the flight landed short of its destination.

45746 — **While in climb the crew was unable to control pressurization.** When the cabin altitude exceeded 10,000 feet the crew declared an emergency and made an emergency descent, landing short of their destination. All alternate means of controlling cabin pressure were tried.

46814 — **During a communication outage, while dodging thunderstorms, the crew lost pressurization and made an emergency descent.** Another flight got a new frequency for all, but while trying to make contact this flight experienced the pressurization loss and declared an emergency. Before contact was regained with ATC, the crew broadcast in the blind for all other aircraft to turn on their landing lights. Finding one aircraft particularly close, they arrested their descent to miss that aircraft. The mechanical problem was subsequently found to be an outflow valve so badly contaminated with sludge that it would not close and allow pressurization.

46855 — **This crew initiated an emergency descent due to uncontrollable cabin pressure and landed short of their destination.** The problem was found to be bird nesting material blocking a radio rack cooling vent, not allowing it to close, and thus venting pressurized air over the side.

47398 — **The aircraft depressurized at FL280.** The reporter felt a pressure change in his ears. The Captain checked the Second Officer's (S/O) panel (the S/O was in the cabin), donned his O_2 mask, actuated the speed brakes and began an emergency descent, without communicating with the reporter. From the Captain's actions, the reporter assumed there was a serious problem, donned his O_2 mask, and alerted the en route Air Traffic Control (ATC) center to the emergency descent. This incident shows a total disregard by the Captain of training in emergency descent procedures that stress crew communication and CRM.

47533 — **The crew was unable to control the cabin pressure by any means, donned their O_2 masks and made an emergency descent to 3,000 feet.** The cabin pressure climbed to 15,000 feet and the passenger O_2 masks deployed. At 3,000 feet the packs restarted, the airplane pressurized and a normal landing was made. After landing, the F/O and the Captain checked with all passengers and none expressed health or injury concerns.

48316 — **A crew at FL350 on an oceanic route experienced an uncontrollable cabin depressurization.** They descended to 10,000 feet and returned to their point of departure. Seventy-nine of the passenger O_2 masks did not deploy automatically, nor could the crew deploy them with the cockpit control switch. The passenger O_2 masks that did deploy were of the chemical generator type and left a burning odor in the aircraft which the crew could not identify. Because of this the crew wore O_2 masks for the remainder of the flight. The crew had never been exposed to the smell of a deployed chemical generator O_2 mask and did not know what caused the burning smell. They should have recognized the smell from exposure to it in initial or recurrent training, as required by FAR 121.417 (c) (2) (i) (C).

48441 — **The crew made a precautionary descent to 10,000 feet and a return to the point of departure when they were unable to control the pressurization.** They did not declare an emergency, but then wondered why the controllers kept asking their intent. On checking, maintenance found a door seal that wasn't seating and an outflow valve so dirty it wasn't working. The aircraft then departed and proceeded to its destination at FL240.

48496 — **Aircraft experienced pressurization problems while climbing out on departure.** The Captain became so involved in solving the problem that he didn't monitor the F/O who was flying the airplane. They were navigating on the wrong airway and had neglected to reset their altimeters so were flying at the wrong altitude. Insufficient attention was being paid to flying the aircraft.

49197 — **While in cruise at FL330 the crew experienced electrical problems which created fluctuating pressurization problems.** In addition, they lost parts of their glass cockpit displays and navigation information. To remain VFR and to control the cabin pressure they squawked "7700" and made an emergency descent. Once communications was regained they received clearance for a VFR approach to their destination.

49389 — **The crew was fatigued from an 11-hour day, including bad weather, was trying to cope with a pressurization problem, and almost flew into the ground on an approach.** The F/O looked up just in time to see the impending disaster, took the aircraft away from the Captain, and made a go-around. The aircraft did make momentary ground contact. Due to deteriorating weather the crew diverted, and they declared an emergency because of the momentary touchdown. The flight landed at the alternate with no problem.

50164 — **En route, at FL310, the aircraft lost pressurization and made an emergency descent.** The O_2 masks deployed and the flight diverted to land short of its destination.

53120 — **The aircraft departed with a defective door seal.** The crew flew at 17,000 feet to their destination and later realized the implications of the door seal letting go in flight at that altitude. They had been warned by the mechanic who checked the door that they should not fly above 10,000 feet. Inexperience and the desire to go led to a potentially dangerous situation.

54596 — **On departure the aircraft would not pressurize and the crew returned to land.** They were informed by another aircraft that it appeared they had two doors open — they subsequently found that both autopressurization doors had failed. They should have seen this on the warning lights for their EICAS. However, they had been taught that the EICAS would automatically recall any warning lights on shifting to ship's power. That is not the case and they did not see the warning lights for the doors before takeoff. The ground school has since changed their teaching on that subject and the crew is now aware of the fact that warning messages have to be manually recalled after certain tests and after shifting to ship's power.

54751 — **This aircraft was dispatched with a restriction to a single pack operating altitude of FL250. Despite this, the Captain operated the aircraft at FL310.** The aircraft had an inoperative air cycle machine in the right air conditioning pack. This was noted in the maintenance log, along with the altitude restriction. En route, after manipulating the pack controls, the Captain felt that the pack was operating and requested FL310. He did this despite the F/Os protests and the MEL restriction in the log. This is a clear case of noncompliance with FAR 91.30.

55845 — **This cargo aircraft would not pressurize after takeoff and the crew flew the remainder of the flight unpressurized and wearing oxygen masks.** Later inspection on the ground showed that an external electrical compartment door had not been properly closed after maintenance work and had not been properly checked by the F/E on preflight. The warning light for the door did not come on until well into the flight.

56019 — **This aircraft lost pressurization at FL260 and made an emergency descent.** The crew used O_2 masks and the passenger O_2 masks deployed. The cause was found to be a piece of aircraft insulation blocking the outflow valve from closing.

58221 — **Precautionary engine shutdown in flight caused loss of cabin pressure and a premature descent.** The aircraft then proceeded at low altitude to its destination.

58293 — **Malfunction of the automatic pressurization control pressurized this aircraft to 2,000 feet below sea level and caused the crew to return to their point of departure.** The crew misread the cabin altimeter as being at 8,000 feet and attempted to descend the cabin manually. At that point they pressurized the cabin for 10,000 feet below sea level. They misread the cabin altimeter by 10,000 feet and were not aware of the proper readings to indicate a cabin pressurized below sea level.

60953 — **In cruise, at FL310, the crew lost pressurization, declared an emergency, and made an emergency descent to 14,000 feet.** The crew continued to their destination at that altitude.

62611 — **This aircraft lost pressurization on climb through 16,000 feet, could not control it manually, and returned to their point of departure.** The F/O was flying the aircraft for a visual approach and the Captain was out of the loop talking on the PA to the passengers and on the radio to the company. As the Captain looked outside he misidentified the runway being approached and called for a go-around. The aircraft was then vectored for another visual approach. The Captain should have been paying more attention to what was happening with the airplane.

62685 — **While in cruise at FL370 this aircraft lost pressurization and made a rapid descent.** The crew was unable to control the pressurization manually, but did not declare an emergency. The cabin altitude never exceeded 12,000 feet and the passenger O_2 masks did not deploy. The crew regained partial control leaving FL200, descended to 12,000 feet and continued to their destination.

62916 — **In cruise at FL220 this crew heard a loud noise followed by a rapid decompression, made an emergency descent and landed short of their destination.** Inspection for damage in flight indicated a vibration near the number 2 engine. Inspection on the ground revealed an 8-16 inch tear in the fuselage. The NTSB determined the tear was caused by metal fatigue resulting from a manufacturing error.

63322 — **When the crew began descent they lost control of the cabin pressure and made an emergency descent.** Upon leveling at 11,000 feet they regained control of the cabin pressure and landed without incident at their destination. Pressurization had not been a problem throughout the flight and no reason for the anomaly was found.

64363 — **The aircraft lost cabin pressure and the crew made an emergency descent.** The crew had been deviating around thunderstorms with engine and wing anti-ice on. They got annunciator lights warning them of the pressurization problem and tried to correct it. They were unable to do so and requested an immediate descent. ATC complied rapidly and made it unnecessary for the crew to declare an emergency.

64705 — **Neither air conditioning pack was operating during climb, cabin pressure continued to climb, and the crew returned to land at the point of departure.** During the climb the Flight Attendants (F/As) complained of poor ventilation. A check of the pack indications showed that the packs were inoperative. On further inspection after landing the Start/Arm switches were found to be in the Arm position — this cuts out the packs on this model of aircraft, and is not the proper position for takeoff. The crew had not run the checklist carefully.

66870 — **The crew was unable to stop a cabin altitude climb and made an emergency descent.** Despite attempts to control pressurization, the cabin continued to climb. The passenger O_2 masks deployed and during the descent, pressurization control was regained. The flight continued to its destination at a lower altitude.

67644 — **This report involves a new type of quick-donning crew O_2 mask which does not perform as required by the FARs.** The harness is designed to inflate away from the mask when the mask is removed from its container, and then deflate for a snug fit after being placed on the wearer's head. Instead, most masks tested by the reporter had the harness inflate inside the mask and jam, so as to require a two-handed operation for donning. FAR 91.32 (b) (1) (ii) requires that a mask can be taken from its hanger/container, and within five seconds and with one hand, placed on the face, and be ready for use. FAR 121.333 (c) (2) has the same requirements and adds: "the certificate holder shall also show that the mask can be put on without disturbing eyeglasses and without delaying the flight crewmember from proceeding with his assigned emergency duties." (It should be noted that on one occasion we have seen this type of mask demonstrated in a cockpit without the reported problem.)

68363 — **This Captain depleted his O_2 supply after testing the regulator in flight and continued the flight to his destination with standby O_2 bottles in the cockpit.** When the F/O left the cockpit for a moment, the Captain put on his mask and tested the regulator. The regulator stuck open and bled off the system. Without the quick-donning masks available for use, the crew did not comply with FAR 121.333 and did put themselves and their passengers in potential danger.

68673 — **The crew was unable to control pressurization during climb and requested lower altitude.** An emergency was not declared and the crew regained control of cabin pressure at a lower altitude. With the concurrence of their company, the crew continued to their destination at the lower altitude.

70236 — **The crew did not turn on pressurization switches and had to make a descent after the cabin pressure started to climb.** Fatigue was a factor, after a long duty day. The crew had read the checklists and responded correctly to the pressurization switch item despite switch position. They turned the switches on at a lower altitude and continued to their destination.

70672 — **An aircraft suffered a decompression at the beginning of descent.** One of the flight attendants, working in an aft galley, recognized her hypoxic symptoms, discovered the passenger masks had deployed, assisted a small child in going to its mother, then passed out from lack of oxygen. She was given supplemental oxygen by another flight attendant and was all right. However, flight attendants are usually trained to don their own masks before assisting others so they will be capable of providing such help. This flight attendant reporter also brought out important considerations concerning chemical oxygen generators. Considerable heat and smoke are caused in the generation process. Reportedly the heat has caused burns to, and the smoke has been inhaled by, crew and passenger alike. In addition, on assuming bracing positions for an emergency landing, a problem arises with the stowage of the paraphernalia from the seat-back style of chemical generators (such as in the DC-10). These canisters are also reported as being so hot as to prevent some passengers from sitting back in their seats and extending their oxygen tubes far enough to initiate the sequence for their canister to provide oxygen flow. This last problem contravenes FAR 25.1450 (b) (1) that says: "Surface temperature developed by the generator during operation may not create a hazard to the airplane or its occupants."

70885 — **This aircraft had a pressurization problem after starting descent from FL310 and made an emergency descent.** Pressurization control was regained at a lower altitude and the flight continued to its destination at that altitude.

73739 — **While in cruise at FL220 this aircraft experienced sudden depressurization and made an emergency descent.** The forward door seal blew out. The crew had difficulty advising ATC because of frequency congestion but finally determined that no traffic conflict had existed.

74860 — **The aircraft experienced a rapid decompression.** The crew followed emergency procedures and made a rapid descent after transmitting in the blind to the center and not receiving a reply. The crew did not squawk 7700 (emergency transponder code) during descent. The reporter felt, in retrospect, that training should include the necessity to be in contact with ATC prior to descent, or at the least, to squawk 7700 so as to alert ATC to the need to clear other traffic in the area of the descent.

81701 — **The crew had a pressurization problem, declared an emergency, and made an emergency descent.** They also suspected they might have an air conditioning fire and requested direct routing to their destination. ATC was going to vector them around military airspace, but after the crew redeclared the emergency, ATC gave them direct routing. The crew felt it should be unnecessary to go into lengthy explanations to get expedited handling after declaring an emergency.

82610 — **The aircraft sustained a partial loss of pressurization and made a descent to regain control.** The crew regained control at a lower altitude and continued to their destination.

82612 — **After partial loss of cabin pressure and deployment of the passenger O_2 masks, the crew made a descent.** They regained control of cabin pressure and climbed back to FL270 to continue to their destination. There, maintenance corrected what they thought was the problem, but the problem recurred on the return flight. No passengers were on board on this second flight.

82754 — **The aircraft lost partial cabin pressure and made a descent after the passenger O_2 masks deployed.** After regaining control of the cabin, they climbed back to altitude and continued on. It was not necessary to declare an emergency because of good handling by ATC. F/As reported that there was no panic amongst the passengers and their reaction was good.

84894 — **Aircraft in cruise at FL310 had an uncontrollable loss of pressurization, made an emergency descent, and returned to its point of departure.** There was confusion about the altitude cleared to in the descent, but nothing was said by ATC about going through an assigned altitude. Passenger O_2 masks did not automatically deploy because cabin altitude never got that high. A burned out outflow valve control motor caused the loss of pressurization.

85640 — **An aircraft in cruise at FL310 experienced an engine explosion and rapid decompression.** The exploding engine left a hole in the fuselage large enough for a man to crawl through. The crew followed emergency training procedures, made an emergency descent, fought the fire, and did all checklists according to their company procedures. The first reporter said it took about 10 seconds to don his O_2 mask and he felt confusion during the initial stages of the emergency. Since time of useful consciousness is measured in seconds at that altitude, he might have approached that length of time and felt the effects of hypoxia. Both reporters felt they had good training to handle single emergency situations. However, they felt that the lack of compounded, multiple-emergency simulator training left them less prepared to cope with this combination of happenings than they would have liked.

87585 — **An aircraft climbing through FL305 experienced rapid decompression, and cabin pressure was lost in about 10 seconds.** The aircraft had been written up for previous pressurization problems but maintenance had been unable to duplicate the problem. Subsequent to this occurrence, a large crack was found in the cabin in the right wheel well area. This problem had been the subject of two previous FAA Airworthiness Directive (AD) notes. The crew made an emergency descent and ran the "EXPLOSIVE DECOMPRESSION" checklist.

88641 — **Aircraft sustained a pressurization loss which the crew could not control and made an emergency descent.** The crew had trouble notifying ATC because of frequency congestion. When they made contact, they were cleared direct to their destination at a lower altitude.

89413 — **Both air conditioning packs quit simultaneously while the aircraft was cruising at FL330 and the crew made an emergency descent.** At 10,000 feet the packs came back into operation and the crew elected to continue to their destination at 10,000 feet.

93641 — **While cruising at FL330, the crew noticed a climb in cabin pressure, could not control it manually, made a descent, and returned to the point of departure.** During this, one elderly passenger with a heart problem required supplemental oxygen. No other problems were encountered.

94955 — **While trouble-shooting a "tail compartment high temp" light, the crew shut down one pack. The other pack would not maintain pressure and they made an emergency descent.**

An emergency was declared and the crew manually deployed the passenger O_2 masks and told the passengers to use them. The crew diverted to their alternate. A loose duct connection in the tail was the cause of the original problem and exacerbated the pressure loss.

96377—**The cabin altitude began to climb, for no apparent reason, on an aircraft in cruise at FL350.** The crew attempted manual control but were unsuccessful. They began an emergency descent and were able to control the cabin altitude when the aircraft reached FL220. The descent was done smoothly enough so that passengers were unaware of it and the flight continued to its destination at the lower altitude. The following quote from the reporter indicates a high level of preparedness and professionalism: "As far as I'm concerned, this was just another day in aviation. No big deal, but felt it would be wise to inform you of the situation that did occur."

97776 — **This crew lost pressurization, declared an emergency, and made an emergency descent.** The problem was with a cargo door seal that blew out. One passenger with a prior heart problem required medical attention and the flight landed short of its destination for that reason.

98080—**Uncontrollable cabin pressure caused the crew to make an emergency descent.** An emergency was declared. The descent was not rapid enough to prevent cabin altitude from exceeding 14,500 feet and the passenger O_2 masks from deploying. The flight landed at its destination unpressurized.

98876 — **The flight crew had an uncontrollable loss of cabin pressure and made an emergency descent.** Attempts were made to control pressure by alternate means. All emergency procedures were followed. Because of a passenger in distress, the flight diverted to a nearby airport. Mention was specifically made of calm, deliberate crew performance.

<u>APPENDIX C</u>

NTSB REPORT SUMMARIES

0488 — **An in-flight B-707 fire in 1973 resulted in 124 fatalities and total destruction of the aircraft after a successful emergency landing.** The fire was fed by material from the aircraft interior. There was a shortage of protective breathing equipment (PBE) with full face masks to allow the crew to fight the fire. The lack of such equipment was addressed.

0527 — **A DC-10 accident in 1973 revealed unsafe conditions in the passenger O_2 system and portable O_2 system.** The chemically-generated passenger O_2 system had design flaws which resulted in poor mounting of the units and the connecting hoses and masks. The portable O_2 systems were not readily available to the crew and did not have supply hoses and full face masks attached. The unsafe conditions have since been corrected.

0713 — **Several rapid decompressions involving DC-10s and L-1011s have uncovered problems with chemically-generated O_2 systems.** Most of the problems have been attributed to a lack of understanding of the systems by both passengers and <u>flight attendants</u>. This Special Study was issued in 1976, and Air Carrier Operations Bulletins (ACOBS) were to be issued to improve training, passenger briefings, and printed instructions on these systems. Other issues such as O_2 mask design were still being debated as late as 1988.

0864 — **A 1977 accident involving a general aviation aircraft led to discovery of a problem with supplemental O_2 masks for general aviation aircraft.** The dilution valve filter dislodged, causing the problem. Tests were done on the particular type of O_2 mask without conclusively demonstrating that the problem was a common one. Eleven years after the accident, there was a Technical Service Order (TSO) regarding O_2 masks in the Federal Register for public comment. If adopted, this TSO should address the problem.

1619 — **A Swearingen Metro taxiing for takeoff at Hot Springs, AR, in 1983, caught fire in the cockpit and was gutted.** All crew and passengers safely evacuated. The aircraft used non-fire-resistant hydraulic fluid and had possible hydraulic leakage and O_2 leakage in the vicinity of the electrical circuit breaker panel. The use of fire-resistant hydraulic fluid and inspection of all hydraulic and O_2 lines for leakage was required to prevent recurrence in this model aircraft.

1636 — **In 1983, A DC-9 in Cincinnati, Ohio had a fire in the left rear lavatory, made an emergency landing, and evacuated the aircraft.** The material in the interior of the aircraft continued to burn during the descent and evacuation, and 23 passengers died. The NTSB cited a shortage of protective breathing equipment with full face masks in the passenger cabin and that was accessible to the crew. An ensuing amendment to the FARs required protective breathing equipment for all crewmembers. In addition, there is an ongoing study of respiratory protection for passengers from toxic environments during aircraft fires as a result of this accident.

1829A — **An in-flight fire on board a Singapore-bound L-1011, in 1985, led to the discovery of malfunctioning passenger O_2 system sequencing valves.** Some of the O_2 masks were neither automatically presented nor were presented when the system was activated from the engineer's panel. An immediate Airworthiness Directive (AD) was issued to correct malfunctioning oxygen initiator sequence timer switches.

1848 — **This 1985 report dealt with the concern of the NTSB regarding passenger comprehension of safety briefings and their performance of tasks described in safety briefings.** These tasks include the use of supplemental oxygen and life vests, and the opening of emergency exits. This concern was addressed at a Public Technical Conference and is still being studied by three working groups set up as a result of that conference.

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