AC 91-8B

DATE 4/7/82

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Washington, D.C.

Subject: USE OF OXYGEN BY AVIATION PILOTS/PASSENGERS

1. PURPOSE. This circular provides aviation personnel with information concerning the effects of atmospheric changes on the body and the use of oxygen.

2. CANCELLATION. Advisory Circular 91-8A dated August 11, 1970, is cancelled.

3. REFERENCES. Federal Aviation Regulations (FAR) Part 135 contains oxygen requirements pertaining to air taxi and commercial operations with small aircraft. FAR Part 121 contains oxygen requirements for air carrier operations. FAR Part 91 contains oxygen requirements for general aviation pilots and passengers including operations conducted under FAR Part 125. The Federal Aviation Administration publications: Aviation Medical Handbook for Pilots; the Office of Aviation Medicine Report, AM 66-28, Oxygen in General Aviation; Physiological Training; and the Airman's Information Manual provide further information regarding the use of oxygen in general aviation aircraft.

4. BACKGROUND. In recent years general aviation aircraft and equipment suitable for operation at the higher altitudes have become more prevalent, while slow or rapid cabin decompression remains a possibility in all pressurized aircraft. It appears that a significant segment of the general aviation pilot population remains uninformed regarding the use of oxygen and related equipment. This circular provides basic information appropriate and necessary to correct that deficiency and to facilitate safe flight at cabin altitudes above 10,000 feet.

5. DISCUSSION.

a. The lack of adequate oxygen in the tissues of the body is known as hypoxia. When the state of oxygen deficiency is sufficient to impair functions of the brain and other organs, hypoxia becomes a definite threat to pilot performance and aviation safety. While there are forms of hypoxia caused by reduced oxygen-carrying capacity of the blood, poor circulation of the blood, and the inability of body cells to utilize oxygen, the most frequent type of hypoxia encountered in aviation is that caused by the reduced oxygen partial pressure in the inspired air as a result of the decrease in barometric pressure at altitude. This type is commonly referred to as altitude hypoxia and is the greatest potential physiological hazard to the pilot in the high altitude environment.

Initiated by: AFO-800/AAM-500

b. The air we breathe is a mixture of gases, essentially 21 percent oxygen and 79 percent nitrogen by volume. At sea level, the atmospheric pressure is usually around 14.7 pounds per square inch, which is equivalent to the weight of a column of mercury 760 millimeters high. One of the physical laws describing the behavior of mixed gases is the law of "partial pressure," which states that the total pressure of a mixture of gases is equal to the sum of the pressures of each gas (partial pressure) in the mixture. For practical purposes, at sea level oxygen exerts a partial pressure of 21 percent of 760 millimeters of mercury (mmHg) or 160 mmHg, and nitrogen 79 percent of 760 mmHg or 600 mmHg. When this air is breathed, it becomes saturated with water vapor in the trachea (windpipe) to prevent damage to the delicate membranes of the lungs. This water vapor now becomes one of the components of the total pressure (760 mmHg), exerting its own fixed partial pressure of 47 mmHg, and thereby lowering the combined oxygen and nitrogen partial pressures to 713 mmHg. When this mixture of oxygen, nitrogen, and water vapor reaches the lungs, a fourth component, carbon dioxide, with its own partial pressure, results in further reduction of the partial pressure of the available oxygen. At sea level, a partial pressure of 103 mmHg is available in the lungs to push oxygen through thin membranes into the surrounding capillaries and then into the red corpuscles of the blood. As the blood moves through the body, the red corpuscles release oxygen to the body tissues for use in the life sustaining processes. On ascent to higher altitudes, the total air pressure diminishes, as does the partial pressure of each of the various gases, even though the percentage relationship of the gases remains essentially the same. However, the partial pressure of water vapor in the lungs remains constant regardless of altitude, thereby further decreasing the usable oxygen as higher altitude is attained. At 20,000 feet, the partial pressure of oxygen in the lungs is only about 33 mmHg. When the oxygen partial pressure is lowered to 30 mmHg (22,000 feet), the supply of oxygen to body tissues becomes completely inadequate to maintain consciousness.

c. A common misconception exists among many 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 in unpressurized aircraft 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. At cabin pressure altitudes above 15,000 feet, peripheral vision deteriorates to a point where only central vision remains, and cyanosis (blueness) of the fingernails and lips develops. The ability to take corrective action is lost in 20 to 30 minutes at 18,000 feet and in 5 to 12 minutes at 20,000 feet, followed soon thereafter by unconsciousness.

d. The altitude sequence cited above assumes gradual ascent, and the individual, to some degree, is able to adjust physiologically to the changing altitude environment, thereby delaying the ultimate effects of hypoxia. In the current age of pressurized aircraft, however, the exposure to higher altitudes as a result of loss of pressurization is of greater concern. In the event of a very slow depressurization, effects of hypoxia could occur insidiously, much in the same time sequence noted above. With a more rapid decompression at high altitude, the sudden change to the ambient environment may be so stressful that physiological compensation cannot occur before the onset of unconsciousness.

e. The period of time between an individual's sudden deprivation of oxygen at a given altitude and the onset of physical or mental impairment which prohibits rational action is considered the "effective performance time" or the "time of useful consciousness." This period represents the time during which the individual can recognize the problem, establish a supplemental oxygen supply and/or initiate a descent to lower altitude. The effective performance time is primarily related to altitude, but is also influenced by individual tolerances, physical activity, and the environmental conditions prior to the exposure. In sudden decompressions to altitudes below 30,000 feet, the effective performance time may differ considerably from the time to unconsciousness. Above 35,000 feet, the period between the effective performance time and time to unconsciousness becomes shorter and eventually coincides with the time it takes for blood to circulate from the lungs to the brain. In a pressurized airplane, the cabin altitude at the time of decompression represents the "environmental condition" prior to exposure. In a rapid decompression to 30,000 feet actual altitude, the average effective performance time would be about 1 minute. At 35,000 feet, average effective performance time is about 30 to 40 seconds. Effective performance time in a decompression to 40,000 feet is reduced to 10 to 20 seconds. At 45,000 feet and above, the time of consciousness is about 10 seconds, and even if the pilot is able to don his mask successfully, a loss of useful consciousness will probably still occur. A "mask-mounted" regulator will provide the user 100 percent oxygen in the first breath, contrary to a "wall-mounted regulator" with a hose to the mask that will contain ambient air. This is of great importance in consideration of hypoxia associated with decompressions to altitudes above 45,000 feet.

f. 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. In FAR Part 91, exposure to altitudes above 12,500 feet up to and including 14,000 feet for periods of more than 30 minutes duration requires the use of supplemental oxygen by the pilot. FAR Part 121 and FAR Part 135 require the flightcrew to use supplementary oxygen at cabin altitudes above 10,000 feet up to and including 12,000 feet for more than 30 minutes. The breathing of supplementary oxygen is necessary to increase the concentration of oxygen in the inspired air in order to maintain the oxygen partial pressure in the lungs at a safe level. Above the altitude of about 33,000 feet, the oxygen tension in the lungs falls progressively even when breathing 100 percent oxygen, and at about 40,000 feet, the oxygen must be delivered under "positive pressure" if the effects of hypoxia are to be prevented.

g. Special consideration must be given passengers with circulatory disorders (heart disease, anemia, etc.), or with lung disease (asthma, emphysema, etc.). Such passengers may require supplemental oxygen to prevent significant hypoxia at lower altitudes than normally expected. This is true also at cabin altitudes in the normal operation of pressurized cabin aircraft. Experience has indicated that some passengers assume that pressurized aircraft have cabin altitudes equivalent to sea level, and many are not aware that their disease may increase their susceptibility to problems related to changes in atmospheric pressure associated with flight.

h. Oxygen systems for civil aircraft are designed to deliver the concentration of oxygen necessary to maintain a partial pressure of oxygen in the lungs sufficient to prevent effects of hypoxia with increasing altitude. Those systems in general use consist of three main components: a mask, a regulator, and a source or store of oxygen, all appropriately integrated. The type of system required to protect the individual is dependent upon the altitude to which it is to be used. There are three distinct types of oxygen systems in use in civil aviation. The "continuous flow" system is the most commonly seen in piston engine general aviation aircraft and in passenger oxygen systems in other aircraft. This system provides adequate supplemental oxygen protection for the flightcrew up to 25,000 feet, and for passengers up to 40,000 feet. The "demand" system delivers a mixture of oxygen and air when the user inhales, automatically matching the oxygen in the mixture to the demand or requirement. This system provides flightcrew members with the protection required up to 40,000 feet. Above 40,000 feet, the "pressure demand" system is necessary. At lower altitudes, this system functions in the same manner as the demand system, but delivers oxygen under pressure when required. Pressure breathing is intended only for short periods of use; for example, to allow safe descent in emergencies.

i. Aircraft oxygen systems are potentially dangerous if not properly installed or maintained. These systems should only be serviced by an appropriately qualified person. Only aviation oxygen should be used to refill the oxygen system. The other two types of oxygen available are medical and industrial oxygen. The difference between aviation oxygen and medical oxygen is that water vapor has been added to medical oxygen. The addition of this "moisture" to the medical oxygen makes it unsatisfactory for aviation use because of the possibility of "moisture" freezing in the regulator. Industrial oxygen is not intended to be used in breathing and, therefore, impurities may not have been eliminated.

j. When supplemental oxygen is required because of the decreased partial pressure of oxygen in the atmosphere, it is imperative that the oxygen equipment be appropriately used. Oxygen masks are available in many styles varying in complexity from light weight plastic disposable masks to units incorporating the regulator, inhalation and exhalation valves, microphone, and special harnesses to achieve rapid donning. Regardless of the style, the purpose of the mask is to cover the nose and mouth and to deliver oxygen in sufficient quantity to maintain the partial pressure of the oxygen in the lungs necessary to prevent hypoxia. To be efficient, the masks must fit and form a "seal" with the face. An inward leak will cause excessive dilution of the oxygen, and an outward leak will waste oxygen and reduce mask pressure during pressure breathing. Improper adjustment of the mask's retaining straps impairs mask-to-face seal. Performance testing by the industry, as well as by various governmental agencies, has revealed that the oxygen mask-to-face seal can also be seriously compromised by the presence of facial hair (beard and/or mustache). Recent tests have shown this to be true for the continuous flow "passenger masks" as well as the demand type masks. The presence of beards and/or mustaches that affect the mask-to-face seal in crewmembers required to perform at optimum levels during flight at altitudes where supplemental oxygen is required, is not compatible with aviation safety.

6. SUGGESTIONS.

a. Pilots who fly to altitudes that require or may require the use of supplemental oxygen should be thoroughly familiar with the operation of the aircraft oxygen systems. A preflight inspection of the system should be performed, including proper fit of the mask. The passengers should be briefed on the proper use of their oxygen system before flight.

b. Federal Aviation Regulations related to the use of supplemental oxygen by flightcrew and passengers must be adhered to if flight to higher altitudes is to be accomplished safely. Passengers with significant circulatory or lung disease may need to use supplemental oxygen at lower altitudes than specified by these regulations.

c. Pilots of pressurized aircraft should receive physiological training with emphasis on hypoxia and the use of oxygen and oxygen systems. Pilots of aircraft with pressure demand oxygen systems should undergo training, experience altitude chamber decompression, and be familiar with pressure breathing before flying at high altitude. This training is available throughout the United States at nominal cost. Information regarding this training may be obtained by request from the Chief, Civil Aeromedical Institute, Attention: Aeromedical Education Branch, AAC-140, Mike Monroney Aeronautical Center, P.O. Box 25082, Oklahoma City, Oklahoma 73125.

d. Pilots should always have available the type of oxygen system required for the highest altitude planned.

e. Pilots of pressurized aircraft should periodically include training exercises with simulated decompression and the emergency use of oxygen equipment in the manner recommended by the aircraft or oxygen system manufacturer.

f. Pilots and other crewmembers operating at altitudes where supplemental oxygen may be required should not have a beard or mustache that will interfere with proper mask-to-face seal.

g. Pilots should understand that while hypoxia is the major problem associated with high altitude flight, it is not the only one. Pilots should be familiar with decompression sickness or "bends," as well as with problems secondary to the expansion of entrapped gases and to ear and sinus blocks. Information on these subjects is available in the references listed in paragraph 3.

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