FOREWORD

Aviation Physiology deals with the physical and mental effects of flight on air crew personnel and passengers. Study of this booklet will familiarize you with some of the physiological problems of flight, and will instruct you in the use of some of the devices that aviation physiologists and others have developed to assist in human compensation for the numerous environmental changes that are encountered in flight.

For most of you, Aviation Physiology is an entirely new field. To others, it is something that you were taught while in military service or elsewhere.

This booklet should be used as a reference during your flying career. Remember, every human is physiologically different and can react differently in any given situation. It is our sincere hope that we can enlighten, stimulate, and assist you during your brief stay with us. After you have returned to your regular routine, remember that we at the Civil Aeromedical Institute will be able to assist you with problems concerning Aviation Physiology.

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INTRODUCTION TO AVIATION PHYSIOLOGY

Human beings have the remarkable ability to adapt to their environment. The human body makes adjustments for changes in external temperature, acclimates to barometric pressure variations from one habitat to another, compensates for motion in space and postural changes in relation to gravity, and performs all of these adjustments while meeting changing energy requirements for varying amounts of physical and mental activity. The human body can adjust to acute and chronic reductions in its oxygen supply by increasing respiratory rate, chemical changes in the blood, and by increasing the production of red blood cells. As efficient as it is, however, a complete absence of oxygen will cause death in approximately five to eight minutes.

In aviation, the demands upon the compensatory mechanisms of the body are numerous and of considerable magnitude. The environmental changes of greatest physiological significance involved in flight are: marked changes in barometric pressure, considerable variation in temperature, and movement at high speed in three dimensions.

Advances in aviation engineering in the past decade have resulted in the development of highly versatile aircraft. Since we are essentially creatures of the ground, we must learn how to adjust to the low pressures and temperatures of flight, and the effects of acceleration on the body. Low visibility, with its associated problems of disorientation and problems related to the general physical and mental stress associated with flight, must be considered. Humans cannot operate these machines at full capacity without physical aids, such as a supplemental supply of oxygen and pressurized cabins for use at altitudes starting as low as 10,000 feet.

We must learn to overcome the handicaps imposed by nature on an organism designed for terrestrial life. In particular, the limiting factors in adjustment of the human body to flight must be appreciated. The extent to which these limiting factors are alleviated by available equipment must be clearly understood. Indifference, ignorance, and carelessness can nullify the foresight, ingenuity, and effort involved in supplying the pilot with efficient equipment.

The following pages will outline some of the important factors regarding physiological effects of flight, and describe the devices and procedures that will contribute to the safety and efficiency of all who fly.

Contents

AVIATION PHYSIOLOGY

AVIATION PHYSIOLOGY QUIZ

1. What happens to the atmospheric pressure around your body as you *ascend* to altitude?

____

2. What is the percentage of oxygen in the atmosphere at Sea Level
(S.L.)?____________________

18K'?____________________

3. If you decompressed from a cabin altitude of 7,000 feet to cruise altitude 35,000 in 30 seconds, what four major *physiological* problems would you encounter?

(1)________________________________ ***(2)***________________________________

(3)________________________________ ***(4)***________________________________

4. Define *hypoxia* and describe the symptoms____________________________________

____

____

5. What is the average *effective performance time* breathing cabin air at;
18,000 feet?_________________________ 25,000 feet?________________________

6. Name several factors that may affect your effective performance time *(EPT/TUC);*
____

____

7. Define *hyperventilation* and describe the symptoms;_________________________

____

____

8. Name the areas of the body subject to *gas expansion* during flight; __________

____

9. A pain in the joint caused by *evolved gas* is known as the ______________ and the treatment procedures are;____

____

10. FAR 91.211 requires the use of *supplemental oxygen* for crew members in unpressurized aircraft at what altitude?__________________________________

11. Following *SCUBA diving*, flying should be *delayed* ___________ hours.

12. FAR 91.211 states that supplemental oxygen should be used during *night flying* at/and above what altitude?_______________________________________

13. *Pilots' disorientation* is commonly called___________________________

14. What would you do to combat *disorientation?*__________________________

____

15. What question regarding aviation physiology do you want to ask?__________

____

____

PHYSICS OF THE ATMOSPHERE

One of the primary problems of flight related to physiology has to do with the fact that the pressure of gases in the atmosphere change as we ascend and descend. It is essential that we have an understanding of the gases found in the atmosphere and their effects upon the body. Other factors, such as temperature change, also need to be understood so we can protect ourselves from these potential hazards.

DEFINITION AND BENEFITS OF THE ATMOSPHERE

The atmosphere is a *gaseous* envelope that covers the earth. The boundary of the atmosphere has been debated for years. While some scientists and physicists set the boundary at 35,000 miles, and a few biologists at 50,000 feet, most scientist, physicists, and meteorologists agree that a more practical boundary is around 1,000 nautical miles. Without the atmosphere there would be no life on earth. The atmosphere provides protection from harmful ultraviolet (UV) rays, cosmic rays, and meteorites. The atmosphere also protects the earth from extreme temperature variations. It supports animal and plant life through its gaseous content and provides rain to grow crops.

COMPOSITION OF THE ATMOSPHERE

The atmosphere is a mixture of gases. It is composed primarily of nitrogen (N_2) and oxygen (O_2). Because atmospheric gases other than oxygen and nitrogen are so low in percentage they will not be considered in this discussion. Therefore from this point on, we will consider the atmosphere to be composed of only oxygen and nitrogen.

GAS	PERCENTAGE	USE BY BODY
Nitrogen (N_2)	80	Major portion of total atmospheric pressure or weight. Gas is inert in the body and is simply stored in tissues and cells.
Oxygen (O_2)	20	Essential for animal life. Supports body metabolism (the catabolic breakdown of glucose for the production of heat energy).
Argon (A)	trace	Noble (no bodily function)
Neon (Ne)	trace	Noble (no bodily function)
Helium (He)	trace	Noble (no bodily function)
Krypton (Kr)	trace	Noble (no bodily function)
Xenon (Xe)	trace	Noble (no bodily function)
Hydrogen (H_2)	trace	(no bodily function)
Carbon Dioxide	trace	End product of metabolism.

(TABLE 1)

METHODS OF EXPRESSING ATMOSPHERE

The gaseous atmosphere surrounding the earth is affected by the gravitational pull of the earth. Atmospheric pressure is the combined weight, or force, of all the atmospheric gases exerted at any given point. In 1924 the U.S. Weather Bureau in conjunction with the Bureau of Standards set forth the values used in measuring a standard day at sea level. This standard atmospheric pressure can be expressed in many different forms, depending on the method of measurement. The various forms of measurement are:

INCREMENT	**STANDARD AT SEA LEVEL**	**METHOD**
Pounds per Square Inch (PSI)	14.7	This is the weight of the atmosphere in pounds exerted on one square inch
Inches of Mercury (in/Hg)	29.92	This is the height in inches that a column of mercury will rise in a vacuum tube when subjected to the weight of the atmosphere
Millimeters of Mercury (mm/Hg)	760	This is the height in millimeters that a column of mercury will rise in a vacuum tube when subjected to the weight of the atmosphere

(TABLE 2)

ATMOSPHERIC PRESSURE

As previously described, the combined weight, or force, of all gases in the atmosphere at any given point gives us our atmospheric pressure. As you ascend from sea level, the atmospheric pressure will correspondingly drop. As atmospheric pressure drops, the air becomes less dense. The primary reason for this phenomenon lies in the kinetic nature of atoms and molecules. Molecules, especially those of a gas, are highly kinetic, or, in a constant state of motion. As pressure around the molecules is reduced, the molecules will travel further apart. This explains why air becomes less dense as altitude increases, thus explaining the phenomenon of gas expansion.

PHYSICAL DIVISIONS OF THE ATMOSPHERE

The envelope of air that surrounds the earth varies in pressure and temperature throughout its entire height. This is due to differential heating of the air by heat radiated from the earth. The rays from the sun strike the earth at a very low angle at the poles and almost vertically at the equator. Thus, more heat is radiated into the air at the equator than at the poles causing the air to rise higher which can vary the heights of the Troposphere division listed below. All the divisions of the atmosphere have their own special characteristics that separate them from the others.

DIVISIONS	ALTITUDES	CHARACTERISTICS
Troposhere	Sea Level - 30,000 (poles) to 50,000 (equator) feet	Variable temperature, water vapor, turbulence, storms, weather, temperature lapse rate
Tropopause	Separates Troposphere and Stratosphere	Region of temperature stability that forms the boundary between the troposphere & stratosphere
Stratosphere	50,000 feet - 50 miles	Relatively constant temperature of -55 degrees Celsius, little water vapor, jet streams, little turbulence
Ionosphere	50 miles - 600 miles	Provides protection from UV rays, gets name from the ionized gas within this layer (UV rays strip electrons from gaseous molecules and creates ions)
Exosphere	600 miles - 1000 miles	Gradually becomes the vacuum of space, so little pressure and density that gaseous molecules rarely collide
Space	Over 1000 miles	

(TABLE 3)

PHYSIOLOGICAL ZONES OF THE ATMOSPHERE

Another way to classify divisions of the atmosphere is from the point of view of the physiological effects on the human body.

ZONES	ALTITUDES	PRESSURE	CHARACTERISTICS
Physiological Efficient Zone	Sea Level - 12,500 feet	760 - 523 mm/Hg	Generally, the body has adapted to operate in the lower regions of this zone. Minor trapped gas problems (ears, sinus, and GI tract.) occur in the lower region of this zone while shortness of breath, dizziness, headaches and fatigue in the upper region if exposure too long
Physiological Deficient Zone	12,500 - 50,000 feet	523 - 87 mm/Hg	The majority of flying is conducted in this zone. The lack of atmospheric pressure causes major physiological problems...hypoxia and decompression sickness
Space Equivalent Zone	50,000 ft - 1000 miles	87 - 0 mm /Hg	This environment is very hostile to humans. "Armstrong's line" is at 63,000 feet and any unprotected exposure above this level causes body fluids to boil. There is a need for a sealed cabin and thrusters on the air/space craft.

(TABLE 4)

PHYSICAL GAS LAWS

A human clothed in everyday street apparel, rapidly exposed to an altitude of 45,000 feet, would become unconsciousness in 9 - 12 seconds with death shortly following. The dangerous element here is the reduced partial pressure of oxygen found at this altitude. Since air is a mixture of gases, it will behave as such and, therefore, is subject to the laws that govern all gases. The following laws explain the effects of reduced barometric pressure and its interplay on the human body.

GAS LAW	EXPLANATION	AVIATION APPLICATION

Dalton's Law $PT = P1 + P2 + ... PN$	The total pressure of a mixture of gas is equal to the sum of the partial pressure of each gas in the mixture	*HYPOXIA* Explains how ascent to altitude reduces the total atmospheric pressure as well as each of the partial pressures associated with the total atmospheric pressure.
Boyle's Law $\frac{P1}{P2} = \frac{V2}{V1}$	A volume of a gas is inversely proportional to the pressure to which it is subjected, temperature remaining constant	*TRAPPED GAS* Explains how pressure change allows the gas to expand and contract in body cavities (ears, sinuses, and GI tract) with increasing and decreasing altitude.
Henry's Law $\frac{P1}{P2} = \frac{A1}{A2}$	The amount of gas dissolved in solution varies directly with the pressure of that gas over the solution.	*DECOMPRESSION SICKNESS* Explains why nitrogen in the body comes out of solution forming bubbles that cause altitude decompression sickness. As altitude increases, pressure decreases and nitrogen will attempt to leave the body and equalize with the surrounding environment. If pressure change is too rapid, the excess nitrogen may form a bubble(s).
Graham's Law *Law of gaseous diffusion*	A gas will diffuse from an area of high concentration to an area of low concentration	*TRANSFER OF GAS IN BODY* Explains the transfer of gases between the atmosphere and the lungs, the lungs and blood, and the blood and the cell
Charles' Law $P1T2 = P1T1$	The pressure of a gas is directly proportional to its temperature.	This gas law has no physiological bearing since that body temperature is a constant 98.6 degrees Fahrenheit.

(TABLE 5)

CONCLUSION

The atmosphere, through its life giving gases coupled with its ability to screen its occupants from the harmful properties of space (cosmic rays, x-rays, meteors, etc..), helps to ensure life on earth. Without an atmosphere, there would be no life as we know it. Additionally, the atmosphere, through aviation, provides career opportunity and a source for potential income. With all its benefits, the atmosphere can be your best friend, but, it can also be a formidable enemy. Humans are ground dwelling creatures that function best at low altitudes. Anytime humans find themselves at extreme altitude they are at a disadvantage. Precautions must be taken to curb the threats of hypoxia, decompression sickness, hypothermia, and spatial disorientation. Appreciate the atmosphere for what it does for you, but, respect it for what it can do to you.

TABLE OF U.S. STANDARD ATMOSPHERE

FEET	*In. of Hg*	*Mm of Hg*	*PSI*	*C*	*F*
0	29.92	760.0	14.69	15.0	59.0
2,000	27.82	706.7	13.66	11.0	51.8
4,000	25.84	656.3	12.69	7.1	44.7
6,000	23.98	609.1	11.91	3.1	37.6
8,000	22.22	564.6	11.77	-0.8	30.5
10,000	20.58	522.7	10.10	-4.8	23.4
12,000	19.03	483.4	9.34	-8.8	16.2
14,000	17.57	446.5	8.63	-12.7	9.1
16,000	16.21	412.0	7.96	-16.7	1.9
18,000	14.94	379.7	7.34	-20.7	-5.1
20,000	13.75	349.5	6.76	-24.6	-12.3
22,000	12.63	321.3	6.21	-28.6	-19.4
24,000	11.59	294.9	5.70	-32.5	-26.5
26,000	10.62	270.3	5.22	-36.5	-33.6
28,000	9.72	237.4	4.78	-40.5	-40.7
30,000	8.89	226.1	4.37	-44.4	-47.8
32,000	8.10	206.3	3.99	-48.4	-54.9
34,000	7.38	188.0	3.63	-52.4	-62.0
36,000	6.71	171.0	3.30	-55.0	-69.7
38,000	6.09	155.5	3.00	-55.0	-69.7
40,000	5.53	141.2	2.73	-55.0	-69.7
42,000	5.03	128.3	2.48	-55.0	-69.7
44,000	4.56	116.6	2.25	-55.0	-69.7
46,000	4.15	105.9	2.05	-55.0	-69.7
48,000	3.77	96.3	1.86	-55.0	-69.7
50,000	3.42	87.4	1.70	-55.0	-69.7
55,000	2.70	68.8	1.33	TEMPERATURE	
60,000	2.12	54.4	1.05	REMAINS CONSTANT	
63,000	1.83	46.9	.907		
64,000	1.74	44.7	.86		
70,000	1.31	33.5	PSF		
			113.2		
74,000	1.08	27.7	77.3		
80,000	.82	20.9	58.1		
84,000	.68	17.3	47.9		
90,000	.51	13.0	35.90		
94,000	.42	10.9	29.97		
100,000	.32	8.0	22.30		

Source: U.S. Standard Atmosphere - 1962 (TABLE 6)

In. of Hg = Inches of Mercury
Mm of Hg = Millimeters of Mercury
PSI = Pounds per square inch
C = Centigrade
F = Fahrenheit
PSF = Pounds per square foot

RESPIRATION AND CIRCULATION

When the human organism is exposed to the various stressors of aerial flight, (physical and psychological) all body functions are affected. However, the areas of the body that are affected most directly are the respiratory and circulatory systems. Therefore, it is important for the individual to be familiar with the actions and limitations of the human respiratory and circulatory systems.

RESPIRATION

A. *The Concept of Respiration*

Respiration is defined as the exchange of gases between the organism and its environment. The more obvious features of this process are the absorption of oxygen from the atmosphere and the elimination of carbon dioxide from the body.

The respiratory system is made up of the lungs, a series of conducting tubes called the bronchi, the trachea, the mouth, and the nose. Air first enters the nasal passages, or the mouth, where it is warmed, moisturized, and filtered. It passes down the throat to the trachea and then into the bronchial tubes and the lungs. Once inside the lungs, the large bronchial tubes will branch 16 times, while getting progressively smaller with each branch. Located at the very end of the 16th branch are the alveoli (air sacs). These air sacs are very small but are large in quantity. There are an estimated 300,000 air sacs total. Though each individual air sac is small, if every air sac was removed from your lungs, and placed on a flat surface in a rectangular fashion, it would occupy a space equal to half a tennis court. Each air sac is surrounded by a dense network of tiny capillaries. The capillaries are so dense that they actually resemble a sheet of blood around each air sac. Each air sac is constructed of a very thin membrane that is just one cell (1/50,000th of an inch) thick. This allows oxygen, as well as other gases, to diffuse across the membrane and into and out of the capillaries and blood.

Cells in the body require oxygen for the burning of food material to produce energy. This process, called *metabolism*, converts glucose (blood sugar) and oxygen into carbon dioxide and water. The carbon dioxide produced from this reaction must be removed from the body. The lungs receive oxygen from the atmosphere which then diffuses into the blood. The blood, at the same time, releases carbon dioxide into the lungs to be exhaled. The oxygen is then transported by the blood to all cells that are low in oxygen. Once the oxygen is in the cell, and metabolism has taken place, carbon dioxide then leaves the cell for the blood. Once in the blood, the carbon dioxide is transported back to the lungs for exhalation.

B. ***Movement of Gases in the Respiratory System***

1. External Respiration

External respiration is the exchange of gasses between the lungs and the surrounding atmosphere. It is estimated that with every normal breath, you will inhale approximately 13 billion trillion oxygen molecules. This number is so large that it is difficult to grasp the sheer magnitude of the amount of molecules that are brought into the lungs. For that reason, the principle of partial pressure will be used. But, as mentioned before, partial pressure relies solely on the number of molecules available for gas exchange.

The partial pressure of oxygen forces oxygen through the air sacs and into the blood (keep in mind that gaseous pressure in physiology depends entirely on concentration of molecules). The partial pressure of oxygen is approximately 20% of the total atmospheric pressure. If at sea level, this would be about 152mm of pressure (20% {oxygen percentage of the atmosphere} of the total atmospheric pressure {760mm}). When a breath is drawn into the lungs, one would expect the partial pressure of oxygen to remain at 152mm. However, the lungs contain other gases that exert a constant pressure (water vapor at 47mm and carbon dioxide at 40mm). These gases tend to displace a part of the oxygen as it reaches lung level. Therefore, these gases reduce the partial pressure of the oxygen at the air sac level to 102mm.

Due to the function of Graham's Law which states: "An area of high gaseous pressure will exert force towards an area of low gaseous pressure", this will cause gases to move back and forth across a gas permeable membrane (such as the air sacs). The high partial pressure of oxygen (102mm) now diffuses through the air sac wall and into the blood. This in turn, raises the partial pressure oxygen in venous blood (blood that has left the cells and therefore is low in oxygen) from 40mm to 102mm. At the same time this is happening, the high pressure of carbon dioxide (approximately 47mm) in the blood will cause some of the carbon dioxide to diffuse into the airsac where carbon dioxide pressure is a constant 40mm.

The same principle that applies to external respiration also applies to internal respiration (the exchange of gases from the blood to the cells). The high partial pressure of oxygen in arterial blood, causes the oxygen to move from the blood into the cells. Due to metabolism, the high partial pressure of carbon dioxide in the cell will causes it to diffuse into the blood for transport to the lungs.

CIRCULATION

A. *Function*

The circulatory system is concerned with the transportation of blood throughout the body. Blood carries food, oxygen, and water to the tissues and waste materials from the tissues. Blood has the additional function of maintaining body heat.

B. *Structure*

The segments of the body that comprise the circulatory system are the heart, arteries, veins, and capillaries.

The heart is a pumping organ capable of forcing blood through the vessels as tissue requirements dictate. The interior of the heart is divided into the right and left halves and each half has two chambers.

The arteries are the vessels that carry oxygenated blood away from the heart. The elastic walls of the arteries are muscular and strong, permitting the arteries to vary its carrying capacity. Small arteries connect larger arteries to capillaries. The capillaries convey blood from the arteries to the veins. They are very small, thin walled, and usually form a network in the tissues in which the exchange of gases take place.

The veins are the vessels that carry deoxygenated blood back to the heart. They have thinner walls and are less elastic than the corresponding sized arteries. When blood enters the veins from the capillaries it is under low pressure. Therefore, some method is necessary to get blood back to the heart, especially from the lower regions of the body. The muscles around the veins produce a milking action of the veins forcing blood toward the heart. Back flow of blood is prevented primarily by valves located in veins.

C. *Composition of the Blood*

Blood is made up of two parts, plasma and solids. Approximately 90% of plasma is water, in which many substances are dissolved or suspended. The solid part of the blood is made up of the white and red blood cells. White blood cells are composed largely of a substance that act as anti-bodies to assist in the fighting of disease and infections. The red blood cells are formed in the bone marrow and there are approximately 35 trillion total in the body. Each red blood cell is largely made up of a substance called hemoglobin. Each red blood cell contains approximately 250 million hemoglobin molecules. Each hemoglobin molecule within the red blood cell can carry 4 molecules of oxygen, so each red blood cell can carry approximately 1 billion oxygen molecules. The secret of hemoglobin is that it contains one atom of iron for every hemoglobin molecule. This gives the blood a chemical attraction for oxygen as well as its red color. The red blood cells carry 95% of all oxygen, while the remainder is suspended in plasma. It can be readily seen that a person who is anemic, for example, does not have enough functioning red blood cells and will begin to suffer the effect of lack of oxygen at a relatively low altitude. The blood of the average person contains about 15 grams of hemoglobin per 100 ml (milliliter) of blood. Each gram of hemoglobin is capable of combining with 1.34 ml of oxygen so the blood could contain 20 ml of oxygen per 100 ml of blood or 20 volumes percent if were completely saturated. Normal arterial saturation is about 95 - 97 % and the oxygen content is 19 volumes percent. The ability of hemoglobin to take up or release oxygen is not a linear function of the partial pressure. However, the relationship is well defined and is usually shown in the form of the oxygen dissociation curve. Venous or return blood has a normal oxygen tension of 40mm and contains 14 volume percent of oxygen, and is 65 - 75 % saturated.

CONCLUSION

The respiratory and circulatory systems of the human body work very simplistic, yet, very efficiently. It gives the human body the capability to adjust and function in a variety of environments. But, the body has its limitations. If the change is too abrupt, then these systems can't adjust quickly enough and the body will suffer the affects. Know the body's limitation at altitude and take appropriate measures to compensate for those limitations.

HYPOXIA

This chapter deals with one of our most important physiological problems. One factor that tends to make hypoxia so dangerous is its insidious onset. Any aviator who flies above 12,000 feet in an unpressurized aircraft without supplemental oxygen is a potential hypoxia case.

TYPES OF HYPOXIA

Hypoxia is described as a state of oxygen deficiency in the blood, tissues, and cells sufficient to cause an impairment of body functions. Anything that impedes the arrival or utilization of oxygen to the cell, places the body in a hypoxic state. There are many conditions that can interrupt the normal flow of oxygen to the cells. The following table describes the various levels at which hypoxia can occur:

Location of Impediment	Common Name	Explanation
Lungs	Hypoxic Hypoxia	Any condition that interrupts the flow of O_2 into the lungs. This is the type of hypoxia encountered at altitude due to the reduction of the partial pressure of O_2.
Blood	Hypemic Hypoxia	Any condition that interferes with the ability of the blood to carry oxygen. Anemia and carbon monoxide poisoning are two conditions that can keep the O_2 from attaching to the hemoglobin within the red blood cell.
Blood Transport	Stagnant Hypoxia	Any condition that interferes with the normal circulation of the blood arriving to the cells. Heart failure, shock, and positive G force along the Z axis will bring about this condition.
Cell	Histotoxic Hypoxia	Any condition that interferes with the normal utilization of O_2 in the cell. Alcohol, narcotics and cyanide all can interfere with the cell's ability to use the oxygen in support of metabolism.

(TABLE 7)

From the table, it is plain to see that any condition that interferes with oxygen's normal path to the cells will bring on hypoxia. While all cells require oxygen to function, some cells require more oxygen than others. Most cells have the ability to store an emergency supply of O_2. The central nervous system (made up of the brain and spinal cord) do not have this ability and also demand a great deal of oxygen (approximately 20% of all oxygen that you inhale feeds the brain). So, if the oxygen supply to the body is reduced, the brain will be one of the first organs to be affected. Another problem is that when the brain starts to feel the effects of hypoxia, the higher reasoning portion of the brain is the first affected. This means that judgment and cognitive skills diminish from the very start.

HYPOXIA SIGNS AND SYMPTOMS

Signs of hypoxia can be detected on an individual by an **observer.** Signs aren't a very effective tool for the victim to use to recognize hypoxia in themselves. Therefore, these signs should not be included with the personal symptoms one gets while experiencing hypoxia. *Symptoms* are the sensations a person can detect while in a hypoxic state. Personal symptoms of hypoxia are as individual as the person experiencing them. A group of people who are hypoxic will, a majority of the time, get the same symptoms. But, the symptoms will appear in a different order and in varying intensities. The greatest benefit in hypoxia symptoms is that the order and the intensity of the symptoms will usually remain constant over the years. This is a great gift, because a pilot will always know what to look for to keep hypoxia in check. Some of the more common signs and symptoms of hypoxia are:

SIGNS	SYMPTOMS
Rapid Breathing	Air Hunger
Cyanosis (Bluing effect of the skin)	Fatigue
Poor Coordination	Nausea
Lethargy	Headache
Executing Poor Judgment	Dizziness
	Hot & Cold flashes
	Tingling
	Visual Impairment
	Euphoria

(TABLE 8)

Of the listed symptoms, visual impairment is probably the least reliable. Your visual field will be affected, but, at such a slow rate that it could go unnoticed. Generally, symptoms will appear before unconsciousness occurs. Except for headache and nausea, there are no other uncomfortable symptoms. Of all the symptoms, euphoria (a false sense of well being) is probably the most dangerous. It puts the pilot in such a state of mind that individual well being, as well as that of the passengers, is a low priority. Another consideration is that, in most cases, hypoxia is very insidious. Any preoccupation with flying duties could be enough of a distraction to allow the hypoxia to progress beyond the point of self help.

EFFECTIVE PERFORMANCE TIME / TIME OF USEFUL CONSCIOUSNESS

Effective Performance Time and the *Time of Useful Consciousness* are two broad and interchangeable terms used to describe the time/hypoxia limit. **Time of Useful Consciousness (TUC)** is described as the period of time from interruption of the oxygen supply or exposure to an oxygen-poor environment to the time when an individual is no longer capable of taking proper corrective and protective action. **Effective Performance Time (EPT)** is described as the amount of time an individual is able to perform flying duties efficiently in an environment with inadequate oxygen supply. The following table will show the TUC/EPT for various altitudes:

ALTITUDE	TUC/EPT
18,000	20 - 30 Min
22,000	10 Min
25,000	3 - 5 Min
28,000	2.5 - 3 Min
30,000	1 - 2 Min
35,000	.5 - 1 Min
40,000	15 - 20 Sec
43,000	9 - 12 Sec
50,000	9 - 12 Sec

(TABLE 9)

The above times are to be used as averages only and are based on an individual at rest. Physical activity at altitude, fatigue, self-imposed stress, and individual variation will make the times vary. Some of the more common factors that will cause your EPT/TUC to vary are:

Rate of Ascent	The faster you ascend to altitude, the shorter your EPT/TUC becomes.
Physical Activity	Any physical activity will reduce your EPT/TUC. For example, if you did 10 deep knee bends at 25,000 feet with your oxygen mask off, your EPT/TUC would be reduced by 50%.
Fatigue	If you enter the cock-pit in a fatigued state, you are less resistant to hypoxia.

Poor Nutrition	The brain feeds exclusively from glucose (blood sugar), so, if your glucose is low, as in hypoglycemia, you're more prone to hypoxia.
Alcohol	Alcohol brings about its own form of hypoxia. When altitude is coupled alcohol, you are a strong candidate for a hypoxic episode.
Over the Counter Medication	Some drugs will cause cells not to utilize oxygen properly and therefore will make you less altitude resistant.

(TABLE 10)

One fact to keep in mind is that, with a rapid decompression to and above 30,000 feet, the average EPT/TUC will be reduced from 1/3 to 1/2 of its original value. This is due to a phenomenon known as reverse diffusion or fulminating hypoxia. This phenomenon is where oxygen, due to the rapid expansion of gas during a decompression, is forced from the lungs and creates a very acute hypoxia that is immediate.

PREVENTIVE MEASURES AGAINST HYPOXIA

There are certain counter-measures pilots can use to prevent hypoxia.

1. Fly at an altitude where oxygen is not required

2. Fly in a pressurized cabin

3. Fly in accordance with FARs (in reference to the use of supplemental oxygen) 12,500 - 14,000 feet for not more than 30 mins.

NOTE

CAMI recommends that on any unpressurized flight to or above 10,000 feet, supplemental oxygen should be used.

TREATMENT FOR HYPOXIA

Hypoxia, under most situations, will be insidious in its onset; thus, its dangerous nature. Fortunately, once the hypoxia is detected and 100% oxygen is administered, recovery is usually only a matter of seconds. Because of the rapid breathing associated with hypoxia, you must slow your breathing rate to prevent hyperventilation.

CONCLUSION

Hypoxia is a constant danger. Many people suffer from ground level hypoxia before they even step inside the aircraft. The insidious nature of hypoxia is its true danger. You must always be on the look-out for hypoxia symptoms. Once hypoxia is recognized, recovery is only seconds away. Know your symptoms. Know your oxygen system and be ready to battle this potential threat to safe flight.

OXYGEN REQUIREMENTS

AIRCRAFT ALTITUDE in feet	BAROM. PRESS mm Hg	BODY H2O PRESS. mm Hg	TRACH. PRESS mm Hg	%O2 INSP. AIR	TRACH. PRESS. pO2	AVEOLAR pCO2 / pO2 mm Hg	%O2 SAT. Hb.	% SUPPLEM. O2 REQUIR. INSP. AIR	TRACH. PRESS. pO2	%O2 SAT. Hb.
SEA LEVEL	760	47	713	.21	149	40 / 103	96%	21%	149mm	96%
5000	632	47	585	.21	122	38 / 78	94%	25%	149mm	96%
10,000	523	47	476	.21	100	36 / 61	90%	31%	149mm	96%
15,000	429	47	382	.21	80	33 / 46	70%	40%	149mm	96%
20,000	349	47	302	.21	63	30 / 33	62%	49%	149mm	96%
25,000	282	47	235	.21	49			63%	149mm	96%
TOTALLY INADEQUATE FOR METABOLIC REQUIREMENT										
30,000	225	47	178	100%	37	40 / 103	96%	84%	149mm	96%
35,000	179	47	132	100%	28	39 / 93	95%	100%	132mm	95%
40,000	141	47	94	100%	20	35 / 59	87%	100%	94mm	87%

PRESSURE/DILUTER DEMAND OXYGEN EQUIPMENT

AIRCRAFT ALTITUDE in feet	BAROM. PRESS mm Hg	BODY H2O PRESS. mm Hg	TRACH. PRESS mm Hg	%O2 INSP. AIR	TRACH. PRESS. pO2	AVEOLAR pCO2 / pO2 mm Hg	%O2 SAT. Hb.	% SUPPLEM. O2 REQUIR. INSP. AIR	TRACH. PRESS. pO2	%O2 SAT. Hb.
40,000	141	47	94	.21	20	INADEQUATE				
				(x 1.00)	94	35 / 59	87%	100%	94mm	87%
				(+ 8mm Hg)	102	36 / 66	92%	100% + PP	102mm	92%
42,000	128	47	81	.21	17	INADEQUATE				
				(x 1.00)	81	33 / 48	71%	100%	81mm	
				(+ 16mm Hg)	97	36 / 61	90%	100% + PP	97mm	90%
45,000	111	47	64	.21	13	INADEQUATE				
				(x 1.00)	64	30 / 34	62%	100%	64mm	
				(+ 33mm Hg)	97	36 / 61	90%	100% + PP	97mm	90%

HYPERVENTILATION

A normal breathing cycle in a healthy adult is considered to range from 12 - 16 breaths every minute. At this rate, a person is able to inhale a sufficient amount of oxygen to support the body's metabolic demand. When breathing at a rate faster than normal, you are considered to be in a state of *hyperventilation*.

Physical Control of the Breathing Rate

The breathing rate can be stimulated or slowed down through voluntary muscle control. This type of hyperventilation is not common. In the days when free diving was popular, the divers would purposely hyperventilate so that they could hold their breath longer than normal. This was a dangerous practice that often led to a diver passing out during the dive.

Chemical Control of the Breathing Rate

Breathing is primarily controlled through chemical means. Due to the process of metabolism, oxygen and glucose combine in the cells where the glucose releases heat and kinetic energy through a catabolic reaction. In this reaction, glucose and oxygen convert to carbon dioxide and water.

$$\mathbf{6O_2 + C_6H_{12}O_6 \longrightarrow 6H_2O + 6CO_2}$$

Where $\mathbf{6O_2}$ is 6 oxygen molecule, combines with $\mathbf{C_6H_{12}O_6}$, which is glucose, will then result in the liberation of $\mathbf{6H_2O}$, or, 6 molecules of water and $\mathbf{6CO_2}$, which is 6 carbon dioxide molecules. This reaction takes place within every cell of the human body and is the basis of metabolism.

About 7% of CO_2 released from the cell will dissolve in simple solution (plasma) and will be circulated to the lungs in this fashion for exhalation. Around 23% combines with red blood cells and forms carbaminohemoglobin. Most of the CO_2, approximately 70%, will be carried as bicarbonate ions and adheres to the following reaction;

$$\mathbf{H_2O + CO_2 \longrightarrow H_2CO_3 \longrightarrow H^+ + HCO_3^-}$$

Where $\mathbf{H_2CO_3}$ is carbonic acid, a hydrogen ion ($\mathbf{H^+}$) is taken from the carbonic acid and forms $\mathbf{HCO_3^-}$ (bicarbonate ion).

As mentioned above, 70% of all CO_2 will be carried in the blood in this fashion. Once the venous blood arrives at the air sac, the reaction will reverse, and CO_2 and water vapor will be exhaled.

1. *Oxygen or Carbon Dioxide?*

So, which gas controls your breathing rate, oxygen or carbon dioxide? Many of you, based on what you have read, would probably answer ***oxygen***. But, the answer is ***carbon dioxide***. The amount of CO_2 liberated during metabolism dictates the amount of bicarbonate, and more importantly, the amount of H^+ (hydrogen ions) in the blood. The hydrogen ion concentration in the blood is monitored by the *chemoreceptors.* The chemoreceptors lie in carotid and aortic bodies. Within these large arteries, the chemoreceptors respond to increasing and decreasing hydrogen ion concentrations. During exercise there is an increased liberation of carbon dioxide. There will be a corresponding increase in hydrogen ion content of the blood. As the chemoreceptors sense this increase, they send a message to the brain instructing it to stimulate the breathing rate. As breathing rate increases, two primary objectives are met. An increase in oxygen uptake to feed the muscles involved in the exercise and to decrease the amount of hydrogen ions, as well as a decrease in CO_2 that built up in the blood as a result of the exercise. This system works very well during exercise. But, if breathing is stimulated voluntarily (as in blowing up a balloon) or involuntarily (as in a fear reaction) without an increase in activity level, this system could bring about unconsciousness.

HYPERVENTILATION

The hyperventilation that most folks are familiar with is the type that accompanies pain or injury, anxiety, and fear. In these situations a person's breathing is controlled emotionally instead of chemically. Due to the natural release of adrenaline, the breathing rate will increase while physical activity remains about normal. In this scenario, a person would begin to breathe rapidly. Since there is no increased activity, the oxygen and hydrogen ion levels of the blood are normal. As the rapid breathing continues, oxygen levels remain normal but the CO_2 levels and the hydrogen ion levels of the blood rapidly drop. This tends to shift the pH balance of the blood towards the alkaline side. The chemoreceptors sense the H+ ion drop and begin to react. The alkaline rich blood, if permitted to be left in the cells long enough, can start to do cellular damage. The brain, in an attempt to defend its self against this pH level, will start to restrict the blood flow to the brain. The brain will go into a hypoxic state and if not reversed in a period of time, will cause unconsciousness. Once the victim is unconsciousness, the breathing rate will slow, and the hydrogen ion level will return to normal level and decrease blood pH.

1. *Recognizing Hyperventilation*

A person hyperventilating will have some definite signs and symptoms;

DIZZINESS	Dizziness is self explanatory. It feels very similar to the type experienced during hypoxia.
BLURRY VISION	As the blood is slowly restricted to the brain, the eyes will also be affected.
TINGLING	The tingling experienced is due to the alkaline-high blood reacting with the sensitive nerves of the extremities.
TWITCHING MUSCLES	As the alkaline-high blood enters the muscle, the muscle will react by twitching. Muscles of the face and the forearms seem to be the most prone.
TETANY (Muscle spasm)	As the alkaline increases in the blood and the blood penetrates deep within the muscle, the muscle will progress from the twitch to an eventual muscle spasm.

(TABLE 11)

Because the symptoms of hyperventilation and hypoxia are so similar, recognition of hyperventilation must be absolute. To make a symptom determination, check your altitude, cabin altitude, and your oxygen equipment.

TREATMENT FOR HYPERVENTILATION

The only treatment is to ***slow the rate and depth of breathing.*** This will have to be a conscious effort on your part. If you are at an altitude where you aren't certain whether it is hyperventilation or hypoxia...TREAT THEM THE SAME. Don the mask and slow your breathing rate.

CONCLUSION

Hyperventilation in aviation is not common. First time flyers (passengers and students) will be the ones most likley affected. If a person in your aircraft is hyperventillating, remember to treat the cause and not the symptoms.

TRAPPED GAS

As you have learned in earlier chapters, gas readily expands with any decrease in pressure. Gas expands in accordance with **Boyle's Law,** which states: "A volume of a gas is inversely proportional to the pressure to which it is subjected, temperature remaining constant." From this law it is apparent that if you reduce the pressure, as in ascending to altitude, gases increase in volume and vice versa on descent. The human body has several cavities that contain varying amounts of gas. Most of these cavities have an opening that will allow the gas to enter and escape. If the opening is reduced in size or closed, then the gas is trapped. Once trapped, it is still subject to gas expansion and compression in accordance with Boyles Law. The result of having changes in gas volume within these cavities without equalization will usually be ***pain***.

BODY AREA	**PROBLEM PHASE OF FLIGHT**	**PHYSIOLOGY**
MIDDLE EAR	DESCENT	On ascent, the air and pressure of expanding gases will escape via the eustachian tube. The base of each eustachian tube is collapsed which acts as a one-way valve to allow gases and liquids to escape and not travel up to the middle ear. On descent, the gas is naturally trapped. Because of the increasing pressure on descent, this pressure will need to be equalized or an ear block will result.
SINUSES	DESCENT or ASCENT (rare)	The maxillary sinuses that sit under the cheekbones and the frontals that lie under the eyebrows have an unobstructed opening that will allow gas to enter and escape. In the event of an upper respiratory infection (URI), the openings will be swollen and possibly closed allowing no route for the gas and pressure to equalize, resulting in a sinus block.
TEETH	ASCENT	A tooth block is very rare. They can occur if you have had recent filling of a cavity. If there is any airspace trapped between the filling and the pulp of the tooth, it will expand on ascent and cause a tooth block.

GASTRO-INTESTINAL	ASCENT	The gastro intestinal tract will always contain a varying amount of gas. This gas is usually a result of the digestion process and can escape by either flatulation or belching. If the gas expands, as in unpressurized flight to altitude, and is not allowed to escape, it could result in a possible syncope (fainting).
LUNGS	DECOMPRESSION	Gas in the lungs will normally enter and escape via the trachea. The easiest way to trap gas within the lungs is through breath holding. This can be a real problem during a decompression. The gases within the lungs will expand rapidly and must escape. If the gases are held in, they could cause possible lung damage.

(TABLE 12)

These gases are forever present in the body and must be considerd for every flight, pressurized or not. The major problems with the ears and sinuses will usually occur from 6,000 feet and lower. This is where the pilot and crewmember are subjected to greatest rate of pressure change. Also, flying with an upper respiratory infection will also increase the chances of a sinus or ear block. The following table will give the recommended procedures for in-flight treatment of trapped gas emergencies.

ALIMENT	SYMPTOMS	TREATMENT
Ear Block	Can start out as a full feeling that will progress to pain. Pain will increases with descent. Can also cause vertigo.	- Level off from descent. - Try ear-clearing maneuvers such as valsalva, aviators jaw jut, yawn, or swallow. - Ascend and try ear-clearing again. - If there is no relief, land A.S.A.P.
Sinus Block	Intense pain under the cheekbones and in the upper teeth (maxillary). Intense pain under eyebrows and in corner of the eyes (frontal).	- Level off from descent. - Try the valsalva maneuver. - Ascend and try sinus-clearing again. - If there is no relief, land A.S.A.P.
G.I. Tract	Progressively increasing pain in the abdominal area with a corresponding increase in altitude.	- Try to pass the gas through flatulating or belching. - If there is no relief, immediate descent.
Tooth Block	A pain in a single tooth where the pain increases with a corresponding increase in altitude.	- Level off from ascent - See a dentist. - If there is no relief, land A.S.A.P.

(TABLE 13)

CONCLUSION

Gases are forever present in the body. These gases act in accordance with the physical laws that govern them. Allowing the gas to escape and equalize with the surrounding environment alleviates the potential for problems. But, if the gas becomes trapped, and the escape route (individual opening for each area) is blocked, the resulting reaction tends to be very painful. When you fly take into account that these gases are present and ready to become a potential problem.

ALTITUDE INDUCED DECOMPRESSION SICKNESS

Most problems associated with flying at high altitude are caused by the drop in atmospheric pressure as one ascends. One of the more dangerous problems an aviator may face is the threat of decompression sickness (possible nitrogen bubbles in body fluids and tissues) at altitude. This problem is not a new one. The first cases of decompression sickness occurred with caisson workers (tunnelers) in the early 1800s. Though the problem of decompression sickness has been studied for nearly 200 years, still there is not a lot known about this potentially life threatening disorder. The patho-physiology of decompression sickness stems from gaseous bubbles (presumably nitrogen) forming and lodging in various tissues of the body. But first, we need to examine how these bubbles form. As mentioned earlier, the problem of decompression sickness stems from reduced barometric pressure at altitude. While at sea level, we are breathing air that is composed of 80% nitrogen. Nitrogen is a noble gas, and can not be metabolized in the human body. This nitrogen that we breathe is taken into the lungs at a pressure of 608mm Hg (80% of the total atmospheric pressure [760mm Hg] at sea level). The nitrogen is then distributed through out the body, via the circulatory system, and stored at a pressure of about 608mm. As long as you remain at sea level, the nitrogen pressure inside the body and outside of the body are in equilibrium. But, when atmospheric pressure is reduced, as in flying unpressurized at altitude, then the equilibrium is upset. This will cause the nitrogen to leave the body. If the pressure differential is not too great, and, the rate of ascent is slow enough, then the nitrogen will leave as a gas and you simply exhale it. But, if the gas leaves too quickly, and the tissues become super saturated with nitrogen, a bubble(s) may form.

Decompression sickness (DCS) describes a condition characterized by a variety of symptoms resulting from exposure to low barometric pressures that cause inert gases (mainly nitrogen), normally dissolved in body fluids and tissues, to come out of physical solution and form bubbles. DCS can occur during exposure to altitude (altitude DCS) or during ascent from depth (mining or diving). The first documented cases of DCS (Caissons Disease) were reported in 1841 by a mining engineer who observed the occurrence of pain and muscle cramps among coal miners exposed to air-pressurized mine shafts designed to keep water out . The first description of a case resulting from diving activities while wearing a pressurized hard hat was reported in 1869.

ALTITUDE DECOMPRESSION SICKNESS

Altitude DCS became a commonly observed problem associated with high-altitude balloon and aircraft flights in the 1930s. In present-day aviation, technology allows civilian aircraft (commercial and private) to fly higher and faster than ever before. Though modern aircraft are safer and more reliable, occupants are still subject to the stresses of high altitude flight—and the unique problems that go with these lofty heights. A century and one-half after the first DCS case was described, our understanding of DCS has improved and a body of knowledge has accumulated; however, this problem is far from being solved. Altitude DCS still represents a risk to the occupants of modern aircraft.

Tiny bubbles

According to Henry's Law, when the pressure of a gas over a liquid is decreased, the amount of gas dissolved in that liquid will also decrease. One of the best practical demonstrations of this law is offered by opening a soft drink. When the cap is removed from the bottle, gas is heard escaping, and bubbles can be seen forming in the soda. This is carbon dioxide gas coming out of solution as a result of sudden exposure to lower barometric pressure. Similarly, nitrogen is an inert gas normally stored throughout the human body (tissues and fluids) in physical solution. When the body is exposed to decreased barometric pressures (as in flying an unpressurized aircraft to altitude, or during a rapid decompression), the nitrogen dissolved in the body comes out of solution. If the nitrogen is forced to leave the solution too rapidly, bubbles form in different areas of the body, causing a variety of signs and symptoms. The most common symptom is joint pain which is known as "the bends."

Trouble sites

Although bubbles can form anywhere in the body, the most frequently targeted anatomic locations are the shoulders, elbows, knees, and ankles. Table 14 (page 32) lists the different DCS types with their corresponding bubble formation sites and their most common symptoms. "The bends" (joint pain) account for about 60 to 70% of all altitude DCS cases with the shoulder being the most common site. Neurologic manifestations are present in about 10 to 15% of all DCS cases with headache and visual disturbances being the most common symptoms. "The chokes" are very infrequent and occur in less than 2% of all DCS cases. Skin manifestations are present in about 10 to 15% of all DCS cases.

MEDICAL TREATMENT

Mild cases of "the bends" and skin bends (excluding mottled or marbled skin appearance) may disappear during descent from high altitude, but still require medical evaluation. If the signs and symptoms persist during descent or reappear at ground level, it is necessary to provide hyperbaric oxygen treatment immediately (100% oxygen delivered in a high-pressure chamber). Neurological DCS, "the chokes", and skin bends with mottled or marbled skin lesions (see Table 1) should *always* be treated with hyperbaric oxygenation. These conditions are very serious and potentially fatal if untreated.

FACTS ABOUT BREATHING 100% OXYGEN

One of the most significant breakthroughs in altitude DCS research was the discovery that breathing 100% oxygen before exposure to a low barometric pressure (oxygen prebreathing), decreases the risk of developing altitude DCS. Oxygen prebreathing promotes the elimination (washout) of nitrogen from body tissues. Prebreathing 100% oxygen for 30 minutes prior to initiating ascent to altitude reduces the risk of altitude DCS for short exposures (10-30 min only) to altitudes between 18,000 and 43,000 ft. However, oxygen prebreathing has to be continued, without interruption, with inflight breathing 100% oxygen to provide effective protection against altitude DCS. Furthermore, it is very important to understand that breathing 100% oxygen only during flight (ascent, enroute, descent) does not decrease the risk of altitude DCS, and should not be used in lieu of oxygen prebreathing. Although 100% oxygen prebreathing is an effective method to provide individual protection against altitude DCS, it is not a logistically simple nor an inexpensive approach for the protection of civil aviation flyers (commercial or private). Therefore, at the present time it is only being used by military flight crews and astronauts for their protection during high altitude and space operations.

PREDISPOSING FACTORS

Altitude

There is no specific altitude that can be considered an absolute altitude exposure threshold, below which it can be assured that no one will develop altitude DCS. However, there is very little evidence of altitude DCS occurring among healthy individuals at altitudes below 18,000 ft. who have not been SCUBA (Self Contained Underwater Breathing Apparatus) diving. Individual exposures to altitudes between 18,000 ft. and 25,000 ft. have shown a low occurrence of altitude DCS. Most cases of altitude DCS occur among individuals exposed to altitudes of 25,000 ft. or higher. A U.S. Air Force study of altitude DCS cases reported that only 13% occurred below 25,000 ft. The higher the altitude of exposure, the greater the risk of developing altitude DCS. It is important to clarify that, although exposures to incremental altitudes above 18,000 ft. show an incremental risk of altitude DCS, they do not show a direct relationship with the severity of the various types of DCS (see Table 1).

Repetitive Exposures

Repetitive exposures to altitudes above 18,000 ft. within a short period of time (few hrs) also increase the risk of developing altitude DCS.

Rate of Ascent

The faster the rate of ascent to altitude, the greater the risk of developing altitude DCS. An individual exposed to a rapid decompression (high rate of ascent) above 18,000 ft. has a greater risk of altitude DCS than being exposed to the same altitude but at a lower rate of ascent.

Time at Altitude

The longer the duration of the exposure to altitudes of 18,000 ft. and above, the greater the risk of altitude DCS.

Age

There are some reports indicating a higher risk of DCS with increasing age.

Previous Injury

There is some indication that recent joint or limb injuries may predispose individuals to developing "the bends".

Ambient Temperature

There is some evidence suggesting that individual exposure to very cold ambient temperatures may increase the risk of altitude DCS.

Body Type

Typically, a person who has a high body fat content is at greater risk of altitude DCS. Due to poor blood supply, nitrogen is stored in greater amounts in fat tissues. Although fat represents only 15% of an adult normal body, it stores over half of the total amount of nitrogen (about 1 liter) normally dissolved in the body.

Exercise

When a person is physically active while flying at altitudes above 18,000 ft., there is greater risk of altitude DCS.

Alcohol Consumption

The after-effects of alcohol consumption, such as dehydration, increase the susceptibility to DCS.

Scuba Diving Before Flying

SCUBA diving requires breathing air under high pressure. Under these conditions, there is a significant increase in the amount of nitrogen dissolved in the body (body nitrogen saturation). The deeper the SCUBA dive, the greater the rate of body nitrogen saturation. Furthermore, SCUBA diving in high elevations (mountain lakes), at any given depth, results in greater body nitrogen saturation when compared to SCUBA diving at sea level at the same depth. Following SCUBA diving, if not enough time is allowed to eliminate the excess nitrogen stored in the body, altitude DCS can occur during exposure to altitudes as low as 5,000 ft. or less.

WHAT TO DO WHEN ALTITUDE DCS OCCURS

- Put on your oxygen mask immediately and switch the regulator to 100% oxygen.
- Begin an emergency descent and land as soon as possible. Even if the symptoms disappear during descent, you should still land and seek medical evaluation while continuing to breath oxygen.
- If one of your symptoms is joint pain, keep the affected area still; do not try to work pain out by moving the joint around.
- Upon landing, seek medical assistance from an FAA medical officer, aviation medical examiner, military flight surgeon, or a hyperbaric medicine specialist. Be aware that a physician not specialized in aviation or hyperbaric medicine may not be familiar with this type of medical problem. Therefore, be your own advocate.
- Definitive medical treatment may involve the use of a hyperbaric chamber operated by specially trained personnel.
- Delayed signs and symptoms of altitude DCS can occur after return to ground level whether or not they were present during flight.

THINGS TO REMEMBER

- Altitude DCS is a potential risk every time you fly in an unpressurized aircraft above 18,000 feet (at lower altitudes if you SCUBA dive prior to the flight).
- Be familiar with the signs and symptoms of altitude DCS (see Table 14) and monitor all aircraft occupants, including yourself, any time you fly an unpressurized aircraft above 18,000 ft.
- Avoid unnecessary strenuous physical activity prior to flying an unpressurized aircraft above 18,000 ft. and for 24 hrs. after the flight.
- Even if you are flying a pressurized aircraft, altitude DCS can occur as a result of sudden loss of cabin pressure (inflight rapid decompression).
- Following exposure to an inflight rapid decompression, do not fly for at least 24 hrs. In the meantime, remain vigilant for the possible onset of delayed symptoms or signs of altitude DCS. If you experience delayed symptoms or signs of altitude DCS, seek medical attention immediately.
- Keep in mind that breathing 100% oxygen during flight (ascent, enroute, descent) without oxygen prebreathing prior to take off, does not prevent the occurrence of altitude DCS.
- Do not ignore any symptoms or signs that go away during the descent. In fact, this could confirm that you are actually suffering altitude DCS.
- Any case of altitude DCS should be medically evaluated as soon as possible, even if symptoms are mild or disappear on descent.
- If there is any indication that you may have experienced altitude DCS, do not fly again until you are cleared to do so by an FAA medical officer, aviation medical examiner (AME), a military flight surgeon, or a hyperbaric medicine specialist.
- Allow at least 24 hrs. to elapse between SCUBA diving and flying.

• Be prepared for a future emergency by familiarizing yourself with the availability of hyperbaric chambers in your area of operations. However, keep in mind that not all of the available hyperbaric treatment facilities have personnel qualified to handle altitude DCS emergencies. To obtain information on location of hyperbaric treatment facilities capable of handling altitude DCS emergencies, call the Diver's Alert Network at (919) 684-8111.

DCS Type	Bubble Location	Signs & Symptoms (Clinical Manifestations)

BENDS	*Mostly large joints of the body (shoulders, elbows, wrists, hips, knees, ankles)*	• Localized deep pain, ranging from mild (a "niggle") to excruciating. Sometimes a dull ache, but rarely a sharp pain • Active or passive motion of the joint aggravates the pain • Pain can occur at altitude, during the descent, or many hours later
NEUROLOGIC	*Brain*	• Confusion or memory loss • Headache • Spots in visual field (scotoma), tunnel vision, double vision (diplopia), or blurry vision • Unexplained extreme fatigue or behavior changes • Seizures, dizziness, vertigo, nausea, vomiting, and unconsciousness may occur
	Spinal Cord	• Abnormal sensations such as numbness, burning, stinging, and tingling around the lower chest and back • Symptoms may spread from the feet up and may be accompanied by ascending weakness or paralysis • Girdling abdominal or chest pain
	Peripheral Nerves	• Urinary and rectal incontinence • Abnormal sensations such as numbness, burning, stinging, and tingling (paresthesia) • Muscle weakness or twitching
CHOKES	*Lungs*	• Burning deep chest pain (under the sternum) • Pain is aggravated by breathing • Shortness of breath (dyspnea) • Dry constant cough
SKIN BENDS (TABLE 14)	*Skin*	• Itching usually around the ears, face, neck, arms, and upper torso • Sensation of tiny insects crawling over skin (formication) • Mottled or marbled skin usually around the shoulders, upper chest and abdomen, accompanied by itching • Swelling of the skin, accompanied by tiny scar-like skin depressions (pitting edema)

PRESSURIZATION AND DECOMPRESSION

The dangers associated with high altitude flying (hypoxia, decompression sickness, ect..) can be avoided by flying in a pressurized cabin. Most modern day aircraft can cruise at altitudes between 25,000 - 51,000 feet and yet keep the cabin at a comfortable altitude of 6,500 - 8,000 feet. With the cabin at such a tolerable altitude, crew and passengers can benefit from these advantages:

Oxygen mask may not need to be worn while pressurized

Decompression Sickness risk is minimal

Less noise and vibration during flight

Better control of heat and ventilation

Less ear & sinus blockage: Descent is around 300 - 500 feet per minute

The basic mechanics of a pressurization system are fairly simple. Ambient air is introduced into a compressor. Once the air is compressed, it heats up very rapidly and therefore must be cooled. The air is then introduced into the cabin. By use of over-flow valves, the air comes in quicker than it leaves, and this creates a high pressure environment.

Pressurization systems aboard various aircraft will use one of three different pressurization schedules:

ISOBARIC	Most commonly used. Cabin altitude is preset and remains there through out the flight
ISOBARIC DIFFERENTIAL	Used mainly in military fighters. Cabin altitude remains constant until a certain cruise altitude is reached where it maintains a constant pressure differential.
SEALED CABIN	The craft carries its own supply of gases to create the pressure environment. Used only for space flights.

(TABLE 15)

Even though there are numerous advantages to pressurized flight, there will always be one major disadvantage...possible loss of pressurization. The FAA currently recognizes three different types of decompressions;

SLOW DECOMPRESSION	Total loss of cabin pressurization in > 10 seconds
RAPID DECOMPRESSION	Total loss of cabin pressurization in 1 - 10 seconds
EXPLOSIVE DECOMPRESSION	Total loss of cabin pressurization in < 1 second (W/ 10 psi pressure change)

(TABLE 16)

From the table above, it is obvious that the major factor that separates the three types is time. There are also factors that dictate how fast an aircraft will decompress with any given scenario. These factors are:

SIZE OF OPENING	With all other factors equal, the larger the opening, the faster the pressure will travel out of the aircraft.
SIZE OF CABIN	With all other factors equal, the smaller the cabin the faster the pressure will depart.
PRESSURE DIFFERENTIAL	With all other factors equal, greater pressure differential = slower decompression.
PRESSURE RATIO	When cabin pressurization is lost, aircraft compressors will continue to operate. The rate at which the compressed air comes in dictates how fast pressure is lost.

ALTITUDE	Higher altitude results in a faster decompression due to less resistance to the air leaving the aircraft.

(TABLE 17)

The faster pressurization is lost, the more detrimental the decompression becomes. Research has shown that effective performance time (EPT) can be cut by as much as 50% in a decompression to and above 30,000 feet. When an aircraft is cruising at 40,000 feet the crew has only seconds to take corrective action. Also, research indicates that the maximum safe altitude an aircraft can decompress and have the crew remain conscious (regardless of having an oxygen mask on) is 48,000 feet.

From the previous statements , the importance of recognizing and taking immediate actions for a decompression is apparent. Here are some common phenomena that occur during a decompression;

NOISE	Noise can come from a leaky door seal, a window departing, a breech of structural integrity or from the aircraft's alarm system.
FOG	On smaller airframes (Lears, Citations, Falcons) the fog could fill the aircraft. On larger aircraft, it stays near the floor.
FLYING DEBRIS/ DUST & DIRT	If there is a large opening, anything not secured down will move towards the opening. These items could cause injuries.
WIND BLAST	As the aircraft looses pressure, it will be felt by crew and passengers as wind blast.
COOLER TEMPERATURES	When the pressure (air) departs the cabin, the temperature will drop.
GAS EXPANSION	As the gas expands w/ decreasing pressure, it will be most noticeable in the ears and G.I. tract of the body.

(TABLE 18)

These decompression phenomena are very common to Rapid and Explosive decompressions. But, during a slow decompression, none of the above listed signs may be present. For this reason, it is felt that the **slow decompression is the most dangerous,** and the aviator must always be on guard against this insidious threat.

Recognition and the immediate execution of emergency procedures for decompression are the most important factors that dictate crew survivability. The common emergency procedures are:

DON MASK	Don mask in 5 seconds or less. Check for flow.
DESCEND	Preferably below 10,000 feet.
LAND A.S.A.P	At nearest suitable installation where appropriate medical.help can be found.

(TABLE 19)

The decompression you will undergo in CAMI's altitude chamber will let you experience all the signs and symptoms while in a safe training environment. This awarness allows you the luxury of knowing what this potential hazard looks and feels like. Reducing the recognition time, this will allow you to don the mask quicker and initiate descent sooner than a pilot who's trying to second guess what's happening.

CONCLUSION

Pressurizing the cabin of an aircraft is a convenient means to escape the hazards of high altitude flight. But, there is one overriding factor that must always be kept in mind; at anytime you may loose that pressurization. When a cabin decompression occurs, the hazards of high altitude flight (hypoxia, decompression sickness, and hypothermia) are immediately brought into the cabin with you. The danger of slow decompressions must be emphasized for they can sneak-up on you and rob you of your judgment or even your consciousness. Always be on the lookout for the signs and symptoms of decompression and then take immediate corrective action.

OXYGEN EQUIPMENT

The development of oxygen equipment has necessarily paralleled progress in aircraft performance. Without protection from the physiological problems at altitude the human becomes the limitation on how fast, how high, and how well an aircraft can perform. Oxygen equipment is just one area of development that has enabled us to fly in the hostile environment above 12,000 feet. In this chapter you will learn the basic principles of oxygen equipment. Emphasis will be placed on the oxygen equipment currently being used. The proper and effective use of oxygen equipment will be stressed and will include the methods of checking the equipment prior to and in flight. The opportunity to use and become familiar with this equipment will be afforded you during the chamber flight phase of your training.

DESIGN

In general, an oxygen system consists of the following components:

a. Containers for storing the oxygen

b. Tubing to conduct the oxygen from the supply source to a metering device.

c. The metering device or regulator that controls the percentage of the oxygen to the user.

d. An oxygen mask to provide oxygen to the user.

OXYGEN STORAGE

Aircraft operators who routinely fly either pressurized or unpressurized at altitudes in excess of 10,000 feet commonly employ a fixed oxygen installation. This consists of containers affixed within the aircraft and serviced through and exterior fuselage valve.

Light aircraft operators who normally fly below 10,000 feet often prefer to use portable oxygen equipment consisting of a container, regulator, mask outlet, pressure gauge, etc., as an integral unit that may be taken aboard the aircraft each time a flight is contemplated at altitudes above 10,000 feet. Portable equipment, in order to avoid weight and bulk problems, is limited in oxygen supply duration. Typical breathing time for four people at 18,000 feet is in the range of 1-1/2 hours using a 22 cubic foot container. Fixed oxygen installations usually offer much longer duration time. Actual times will depend upon size of oxygen containers in the system, and the number of people using the system.

OXYGEN STORAGE METHODS

Gaseous oxygen is stored in containers at low pressure (400-450 psi) and high pressure (1800-2200 psi). The high pressure system is used very extensively in general and commercial aviation.

The latest developments in oxygen systems for aircraft make use of chemical action and are termed solid state oxygen systems. Solid state oxygen has come into its own through its use in new jumbo jet transports. It has weight, duration, and storage advantages not found in other oxygen systems currently in use.

1. AVIATORS BREATHING OXYGEN

Aviators gaseous oxygen is designated Grade A, Type I Oxygen, Military Specifications MIL-0-27210D. It must meet a minimum purity requirement, excluding moisture content, of 99.5 % by volume and may not contain more than 0.005 mg of water vapor per liter at 760 mm Hg and 68 degrees F. (20 degrees C.). It must be odorless and free from contaminants, including drying agents. Do not confuse aviators breathing oxygen with "technical" oxygen or "medical" oxygen.

OXYGEN STORAGE SYSTEMS

Low pressure gaseous oxygen has a pressure range of 400 - 450 PSI.

Cylinder Types and Capacities

Internal Volume (Cu inch)	**Length (inches)**	**Diameter (inches)**	**Available Oxygen (Cu foot)**
280	14.5	5.75	3.8
280	15	5.75	3.8
500	23.5	5.75	6
1,000	18	10	13.8
1,000	44.5	5.75	13.8
2,100	24.5	12.5	29
18,000	49.5	24.5	248

(TABLE 20) High pressure gaseous oxygen - pressure range 1800 - 2200 PSI

Cylinder Types and Capacities

Internal Volume (Cu in)	Length (inches)	Diameter (inches)	Available Oxygen (Cu ft)
205	14	5.34	13.7
295	18.5	5.34	19.6
386	15.37	6.92	25.6
514	19.25	6.92	34.2
646	23.5	6.92	42.9

(TABLE 21)

REGULATORS AND MASKS

A. Continuous Flow

The continuous flow oxygen regulator provides a flow of 100% oxygen. The rate of flow is usually measured in liters per minute. Flow rate may be controlled by turning a valve. Several regulators are offered that employ an altitude sensing aneroid to change the flow rate automatically.

Continuous flow masks use an oronasal face piece to receive the oxygen flow. The face piece does not usually have an air tight or oxygen tight face seal. This permits the user to exhale around the face piece or through small face piece ports or openings designed to dilute the oxygen with ambient air.

Continuous flow masks in use today make use of a rebreather bag. This bag is attached to the mask and enables the wearer to reuse a part of the exhaled oxygen. Usually, there is a device in the oxygen hose, which enables the wearer to see that oxygen is flowing through the system.

B. Demand and Pressure Demand

The demand regulator, as the name implies, operates to furnish oxygen only when the user inhales or demands it. A lever may also be employed to enable the regulator to automatically give either a mixture of cabin air and oxygen or 100% oxygen. This is referred to as the automix lever. The regulator is set up to give varying amounts of oxygen to the user depending upon the altitude attained.

The demand mask is designed to accommodate an air tight and oxygen tight seal to the face. This mask is expected to retain all of the oxygen inhaled into the mask by the user and not be diluted by entry of outside air. The demand regulator and mask provide a higher altitude capability than most continuous flow systems. They may be safely used to altitudes of 40,000 feet.

Pressure demand regulators are designed to furnish oxygen on inhalation either as a mixture of air and oxygen or 100% oxygen. This regulator also provides a positive pressure application of oxygen to the mask face piece enabling the users' lungs to be pressurized with oxygen. This is of great benefit at extreme altitudes, such as 40,000 feet or higher. The oxygen pressure flow may be either manually controlled or function automatically on some regulators at a certain altitude through aneroid action.

The pressure demand masks are designed to create an air tight and oxygen tight seal. The inhalation and exhalation valves are specially designed to permit oxygen pressure build up within the mask face piece and thus supply oxygen under pressure to the lungs.

It is essential that demand and pressure demand masks be properly suspended by an adequate head harness and that the masks be afforded tension adjustments for the user to obtain a leak proof seal to the face. The higher you fly, the more critical this adjustment becomes.

PRE-FLIGHT OXYGEN EQUIPMENT CHECK

Prior to flight a person should locate the oxygen mask, practice donning it, and adjust the head harness to fit: locate and check thefunction of oxygen pressure gauges, flow indicators and connections: and check the quantity of oxygen in the system. The mask should be donned and the oxygen system should be checked for function.

A physical check of the mask and tubing to spot any cracks, tears, or deterioration would also be indicated. If a person is using a mask connection to an individual regulator, check for regulator condition and lever or valve positioning as required by that particular system.

GENERAL RULES FOR OXYGEN SAFETY

Do not inspect oxygen equipment with **greasy hands**. Do not permit accumulation of oily waste or residue in the vicinity of the oxygen system.

Do not use **surplus oxygen equipment** unless it is inspected by a certified FAA inspection station and is approved for use.

Some military components use oxygen containers stressed for a pressure of 450 PSI (low pressure). Needless to say, a hazard exists if a person attempts to put 1800-2200 PSI oxygen pressure in this type container. Make sure that high pressure oxygen containers are marked to indicate 1800 PSI before attempting to fill the container to this pressure. Most individuals do not possess the equipment necessary to fill an aircraft oxygen container from another source of high pressure oxygen. It is recommended that oxygen system servicing be done at FAA certified stations such as are located at some fixed base operations, terminal complexes, etc.

After any use of oxygen, give careful attention to ascertain that all flow is shut off before lighting cigarettes, etc.

Oxygen systems must be engineered to protect the individual to the maximum anticipated flight altitude of the aircraft. Before purchasing any oxygen equipment, it is recommended that you inform the distributor on such factors as peak altitude to be flown, number of persons who will use the oxygen system, expected oxygen breathing duration, range of the aircraft, and any other information you think will be helpful in designing a proper oxygen system. Do not make any modification to the system without first consulting the supplier or distributor.

Do not place portable oxygen containers in the aircraft unless you fasten them securely to insure against displacement in the event of turbulence, unusual attitudes, etc.

ALTITUDE CHAMBER FLIGHT

Altitude chambers have proven to be very valuable training devices. They give aviators the chance to experience many of the hazards of high altitude flight in a controlled and safe environment. Some people look at altitude chamber flights as "practice bleeding" and unnecessary for teaching and demonstrating the potential hazards that face all pilots and crewmembers. It is strongly felt by the majority of Physiologists, AMEs and most pilots that the best way to learn about altitude effects is by experience. Altitude chambers allow you to experience unpressurized flight: gas expansion, rapid decompression, hypoxia, and the use of oxygen equipment.

THEORY OF OPERATION

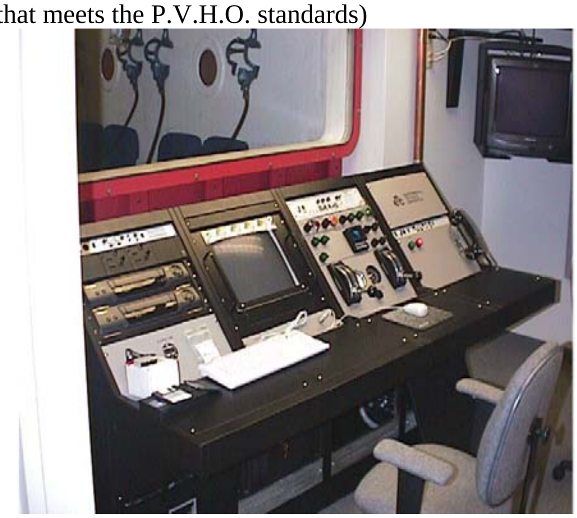
Altitude chambers work in accordance with a gas law that states "When you remove the gas you will also remove the pressure of the gas". The altitude chamber employes a vacuum pump to remove gas/pressure from the chamber. As the pressure is removed, it simulates the corresponding pressure of a particular altitude. This creates a low pressure in the chamber, and coincides with the low pressure one experiences during unpressurized flight.

Dr. Paul Bert and the first altitude chamber (circa 1874)

HISTORY OF ALTITUDE CHAMBERS

The first altitude chamber flight for training purposes took place in March 1874. Dr. Paul Bert of France (noted in history as the first practicing flight surgeon) used a diving bell and a steam driven vacuum pump to train two young men on the hazards of high altitude balloon flights. Through the years, the military has conducted altitude chamber training for all crewmembers flying on military aircraft. The FAA began altitude chamber flights for civilian pilots and crewmembers in 1962. The FAA has enjoyed a very safe history with its chamber flight profiles; undesirable reactions have occurred in just 9.9% of all chamber participants. And most of those reactions were mild (chiefly, earblocks and sinus pain).

(CAMIs new altitude chamber delivered in 1998. The only chamber to date that meets the P.V.H.O. standards)



(Control Console with manual and computer controls)

THE FAA/CAMI ALTITUDE CHAMBER FLIGHT PROFILE

The chamber profile currently used by CAMI (Civil Aeromedical Institute) was instituted in 1973. It has proven to be a very effective and comfortable flight profile when time, safety, and training effectiveness are considered. The flight profile will consist of:

1. *Pre-Flight Briefing*	This will normally take place in the classroom and is intended to familiarize the student with the flight profile and safety aspects of the altitude chamber
2. *Oxygen Equipment Lab*	This will occur inside the altitude chamber and is intended to familiarize the students with the oxygen equipment they will be using during the flight. Correct donning procedures, mask fitting, and regulator function will be demonstrated by each student.
3. *Ear & Sinus Check*	At this point, the chamber door will be closed and the chamber will ascend at 3,000 feet per minute to a simulated altitude of 6,000 feet. After ensuring the comfort and condition of each student, the chamber will descend at 3,000 feet per minute to 2,000 feet where, once again, the instructor will assess the condition of each student.
4. *Rapid Decompression*	The chamber will ascend to 8,000 feet at 3,000 feet per minute. From 8,000 feet, the chamber will rapidly climb to 18,000 feet in 8 - 10 seconds. This is known as a rapid decompression.
5. *Ascent to 25,000 feet*	The chamber will continue to ascend at 3,000 feet per minute to 25,000 feet for the next demonstration.
6. *Hypoxia Demonstration*	At 25,000 feet, the chamber is at the peak altitude of the flight profile and this is where students will have a chance to experience their personal symptoms of hypoxia. There will be a five minute limit for students to acquire their symptoms.

7. *Descent to Ground*	The chamber will descend to ground level at 3,000 feet per minute.

(TABLE 22)

SPATIAL DISORIENTATION
SENSORY ILLUSIONS OF FLIGHT
VERTIGO

The terms listed in our title are often used interchangeably even though their exact meanings differ somewhat:

SENSORY ILLUSION	A false or misinterpreted sensory impression; a false interpretation of a real sensory image.
VERTIGO	A hallucination of movement. A sensation of rotary motion of the external world or of the individual.
SPATIAL DISORIENTATION	Loss of proper bearings; state of mental confusion as to position, location, or movement relative to the position of the earth.

(TABLE 23)

Sensory receptors in various parts of the body provide the brain with information relative to your position in your environment. The eyes, vestibular apparatus, and muscle senses practically tell you *which way is up.* In flying, many conditions you encounter can cause conflicts, or illusions, in these sensory functions. Cockpit confusion might be another term for disorientation, since the information from your senses and from your instruments may be contradictory.

To understand the functions of the organs of equilibrium and how interpretations of these senses may lead to sensory illusions and spatial disorientation is a complex but rewarding undertaking.

SENSORY SYSTEMS INVOLVED IN EQUILIBRIUM

The sensory organs of the body associated primarily with maintaing body equilibrium are the eyes, semicircular canals (vestibular apparatus), and the skeletal muscles (proprioceptors).

A. THE EYES

The eye acts as the receptor organ for visual sensations. These sensations establish impulses in the cone and rod cells and the impulses travel the optic nerve to the brain for interpretation. The eye is very reliable for orientation, provided adequate reference points are available. When flying, however, you are at a disadvantage when trying to interpret visual cues. An object seen from the air often looks quite different than objects seen from the ground. Also, you are used to having the ground extend to the horizon. In the air you lack the visual cues that a continuous background provides for recognizing objects and deciding their size and distance. A very common mistake is in interpreting the lights that you see at night. Pilots can become confused about the relationship between their own motion and the false motion of fixed lights on the ground. Thus, a pilot may decide that a fixed light on the ground is another airplane traveling in the opposite direction.

If you cannot see the horizon, you may mistakenly choose some other line as a reference and, for example, may fly parallel to a tilted cloud bank instead of the ground. Consider what happens when no clouds are present and the horizon is obscured by haze or adverse lighting conditions. In such a situation you are apt to be completely without reference, which amounts to *flying blind.* In Alaska and other similar areas, this problem is particularly severe due to haze and light reflected from the snow covered ground. Under such conditions, sensory illusions in flight are only part of the problem; a noticeable loss of depth perception increases the hazard.

All these illusions are mistakes in interpretation caused by inadequate information on which to establish a reference. Your eyes are reporting correctly to your brain, but there isn't enough information for the brain to interpret.

This situation is worse at night than during the day, for your eyes are furnishing less information. Under such conditions your eyes can send false messages to the brain.

Have you ever been stopped at a traffic signal and then had another automobile pull along side? Although you were stopped, did you have the illusion your car was backing up slowly only to find that you were indeed stopped and the other car was moving up slowly? This is one simple illustration of sensory illusions. There are numerous others that can and do occur while flying aircraft in both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) conditions.

B. PERCEPTION of the SKELETAL MUSCLES

The tension of the various muscles in your body assist you in determining your position within a frame of reference, as well as any motion with respect to this reference. Compared to the eyes and vestibular apparatus, however, these muscles *(known as the proprioceptors)* play a very small role in determining orientation.

However, no matter how small a part the proprioceptors play in determining perceived direction in the air, they can give some indication of position by the pressure of your body in the seat of the aircraft and the sensation that gravity is being applied along a line from the earth passing vertically through the seat. The feeling can occur regardless of the aircraft's reference point to the earth. This means that even though the muscle sense indicates to the pilot that the aircraft is flying a straight and level course, the aircraft may actually be in a coordinated turn.

C. THE VESTIBULAR APPARATUS

The Inner Ear consist of an auditory and non-auditory portions. The latter is primarily associated with equilibrium and contains the three semicircular canals. The semicircular canals are filled with a thick fluid and each canal lies at an approximate 90 degree angle to the other.

One end of each canal is enlarged and in this area is a mound of sensory hair cells. Angular acceleration, or rotation, of the body along either the yaw, pitch, or roll axis will move the fluid in a respective canal. This movement displaces the sensory hairs and an impulse is sent to the brain to be interpreted as motion about a known axis. The hairs that project into the fluid are extremely fine, light, and sensitive. Any acceleration greater than 2 degrees per second will cause the hairs to displace and an impulse is sent to the brain that indicates which way the hairs are bent, the brain then figures out the plane of rotation. Since the canals lie in different planes, they can report movement in all three dimensions (yaw, pitch, and roll). This system works fine for sudden, short turns, but, if the turn continues at a constant rate for a period of time, (approximately 25 seconds) the motion of the fluid catches up to the speed of the canal walls, and the hairs are no longer bent. In this scenario, a pilot would initially feel a turn to the right, but, after 25 seconds, as long as the rate of the turn is constant, the pilot would feel as though the turn has stopped, when in actuality, this pilot is still turning to the right.

Once the turn to the right is detected, and the turn is stopped, the fluid in the canal will continue to move. In this situation, the hairs that were straight because the fluid and canals were moving at the same rate, would suddenly bend in the opposite direction. This would cause an opposite sensation as though one was now turning hard to the left. An untrained pilot in this situation would, more than likely, turn the aircraft back to the right to compensate for the ***perceived*** left turn. As a result, a pilot would try to counteract this imaginary motion by turning back into the original turn or spin. This is the physiology behind the classic *Graveyard Spin or Spiral.*

As angular acceleration begins, the canal(s) wall will rotate as the body rotates. The fluid in the canal will lag behind causing the sensory hairs to deviate from their normal erect position (see example A). As the rotation continues at a constant rate for approximately 25 seconds, the fluid will move at the same rate as the canal, the sensory hairs will come back to the erect position, and the sensation of turning will not be felt (see example B). If the rate of the turn decreases or if the turn stops, the fluid, due to inertia, will continue to move and will bend the sensory hairs in the opposite direction (see example C).

When the brain perceives angular motion from a canal, it will cause the eyes to react to the motion. In an attempt to keep everything in your visual field during rotation, the eyes will sweep opposite of the plane of rotation. So in the example of the person turning to the right, the eyes would sweep to the left. This system works well during the rotation. The problem is that when the angular acceleration stops, and the fluid in the canals continues to, the eyes continue the sweeping motion for up to 30 seconds of completion of rotation. This condition is called ***nystagmus***. A pilot in this situation could, for example, be turning onto a final approach. After the turn is completed, the pilot, who is trying to scan VASI bars for example, would find that the bars are sweeping side to side, making them very tough to scan.

During angular acceleration in one plane of motion, the pair of canals (one in each ear) lying in that plane will be the only ones stimulated. But if one were to deviate one's head position during angular acceleration, another canal would be stimulated. This would send two conflicting impulses to the brain. The brain would have a difficult time trying to process the information coming from the two canals, and would find a "happy medium" to accommodate the signal. This gives a person a very strong illusion called ***Coriolis.*** In this scenario a pilot would be turning to a new heading, if the pilot moves the head during this turn by looking down at an approach plate or up at a switch or toggle, this could give the pilot a sensation that the aircraft is making a violent roll or pitch. An untrained pilot may possibly put the aircraft into an unusual attitude.

If an aircraft slowly tips to one side while a pilot is distracted, the rate of the roll can be so slow that the pilot may not detect it. This is called ***Sub-Threshold Acceleration*** and can be a very dangerous illusion. Any angular acceleration greater than 2 degrees per second will be detected by the semicircular canals. If the rotation is slower than this rate, angular accelaration may go unnoticed. This is the basic physiology behind a common illusion called the ***leans***. A pilot in this situation would, as mentioned above, slowly roll to the right or left. The rotation, if less than 2 degrees per second (sub threshold), would be unnoticed. Once the pilot checks the instrument panel and detects the roll, the pilot would attempt to go straight and level. When the pilot comes about level there will be a strong sensation of rolling to the opposite side. An untrained pilot may put the aircraft back into the initial roll because that "feels normal."

FLIGHT FACTORS CONTRIBUTING TO SPATIAL DISORIENTATION

1. Changes in angular acceleration.

2. Flying in Instrument Flight Rules (IFR) conditions.

3. Low level flight over water.

4. Frequent transfer from Visual Flight Rules (VFR) to IFR conditions.

5. Unperceived changes in aircraft attitude (Sub-Threshold Acceleration)

WHAT TO DO TO BEAT SPATIAL DISORIENTATION

From all this you can see that, individually treated, each type of illusion can cause a great deal of trouble. Since this is precisely what may happen if you are not careful, let's see what you can do to beat these illusions.

First of all, you probably appreciate the fact that sensory illusions or vertigo are problems that usually show up under instrument conditions. Whenever the visibility is poor enough to prevent you from double-checking your equilibrium sense with your eyes, your equilibrium system is undependable. That is why your aircraft provides you with an artificial equilibrium system for indicating bank angle (turn & bank indicator), aircraft attitude (attitude indicator), pitch angle (VSI), and so forth. This system is much more reliable than anything you are equipped with, but it's not easy to use, primarily because you were not born with it. All your life on the ground you have been navigating by your eyes, and you are accustomed to doing what they tell you to do. Now, when you fly by instruments, you are told to ignore your senses and put your faith in dials and indicators.

1. Use Your Head.

There are several points to remember about instrument flying. The first is that you can learn to do it, but you have to use your head. Flying by instruments is a skill that can be highly developed. You have to read and interpret the instruments and act accordingly. At the same time, you must have confidence in the instruments and ignore any other signals your body gives you.

This procedure usually slows you down a bit. Tests show that flyers interpret the actual horizon about one-fifth of a second faster than they interpret instruments. Furthermore, pilots make a recovery from a dive about one and a half second faster under VFR conditions as opposed to IFR conditions. Pilots are also more susceptible than usual to the stresses of flight such as fatigue, oxygen lack, and anxiety. These stresses may reduce the pilot's ability to think straight, so there is the danger of forgetting to use instruments when things get tough. Anything that produces an emotional upset is likely to disrupt conscious mental processes and make the pilot much more susceptible to illusions or false sensation.

2. Rare Sensations

The second point to remember is that the illusions that have been described in this section are relatively rare. Believe it or not, this can actually be a disadvantage. You learn to adjust to the sensations of normal flight as you gain flying experience, but the possibility remains that you will suddenly encounter a vivid illusion you have never experienced before. If you don't know what the illusion is or how you can handle it, you are likely to get panicky and let your emotions take over. When this happens, you are putting your life in the hands of your senses, and under such conditions they may prove to be inadequate.

3. Trust Your Instruments.

Last, but not least, remember that many accidents occur as a result of indecision about going on instruments. With poor visibility you may begin to go on instruments too late and then sensory illusions can make you believe your instruments are wrong.

There is just one way to beat false interpretation of motion. Put your faith in your instruments and not your senses. Know what kind of tricks your senses can play on you, keep calm, and have confidence in your instrument panel. Once you have acquired this confidence, you can fly at night and in weather as easily as if you were following railroad tracks, two creeks, and a cornfield back to the airport. The moral is simple: The transition from VFR to IFR must be a complete and trusting transition.

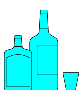
CONCLUSION

Anytime there is low or no visual cue coming from the outside of the aircraft, you are a candidate for spatial disorientation. Developing the dicipline to trust your instruments is achieved through training practice. Trusting what your instruments are telling you and disreguarding what your body is telling you is the key to control disorientation and its dangerous illusions.

SELF IMPOSED STRESS

In defining self imposed stress it is necessary first to define stress. In the DORLAND'S ILLUSTRATED Medical Dictionary, stress is defined as "the sum of the biological reactions to any adverse stimulus, physical, mental, or emotional, internal or external, that tends to disturb the organism's homeostasis (body's natural balance)". Should these compensating reactions be inadequate or inappropriate, they may lead to disorders.

It is difficult to measure the full effect that stress can have, but we are aware of some of the contributing factors that can increase the amount of stress one is experiencing. These contributing factors are known as self-imposed stresses. Among these factors is the use of alcohol, drugs, tobacco, physical fitness, diet, fatigue, and disruption of the circadian rhythm problems. As we determine the effects of each of these stresses, it is also important that we point out how each might affect your job performance, or in this case, your ability to perform your flying duties efficiently.



ALCOHOL

We are all aware of the dangerous side effects that alcohol has on your driving ability. It's not difficult to figure out then that alcohol, in any quantity, can have an adverse effect on your flying capabilities. Before we get too in deeply into the effects of alcohol, it is important to note how it generally affects the human organism.

The active ingredient in beverages, such as beer, wine, and liquor is ethyl alcohol. Alcohol itself is considered an anesthetic drug that, when ingested in any quantity, is considered a depressant. As a result, cell metabolism is depressed which is most noticeable in the brain. Since cell metabolism is depressed, so too is the utilization of oxygen being delivered to the cells. What is experienced as a result is histotoxic hypoxia. Below is a list of performance losses caused by alcohol:

- Judgment *(Normal cautionary attitudes are lost)*
- Speed and strength of muscular reflexes.
- Inhibitions and worries lessens
- Skill reactions and coordination
- Insight into existing capabilities
- Judgment, comprehension, fine attention
- Dehydration
- Efficiency of eye movement and hearing
- Sense of responsibility
- Relevance of response
- Ability to see under dim illumination
- Memory and reasoning ability
- Altered perception to situation

Since every individual is physiologically different, the symptoms experienced from the ingestion of alcohol will vary in severity and intensity. One reason for this variance is the rate of alcohol absorption, which depends on such things as the following:

- Type and quantity of food in the stomach
- Concentration of alcohol in the beverage
- Body weight
- Degree of dehydration
- How fast it is consumed

Another factor is the rate of absorption of the alcohol. On average, our liver is capable of filtering approximately a third of an ounce of pure alcohol per hour. To give you a better picture of the time it takes to absorb certain types and amounts of alcohol, the list below show some common drinks and their alcohol content:

Type of Liquor	***Size***	***Percentage of Alcohol***
Wine	4 oz Glass(113 g)	12
Light Beer	12 oz Glass(340 g)	4
Champagne	4 oz Glass(113 g)	12
Vodka	1 oz Shot(28 g)	50
Whiskey	1.25 oz Shot(35 g)	40
Aperitif Liquor	1.5 oz Glass(43 g)	25

(TABLE 24)

According to the chart if you were to take two shots of vodka in a one-hour period, it would take 3 hours for your body to completely metabolize the alcohol (again keeping in mind the other factors, such as food in the stomach and/or dehydration.) Since the effects of alcohol are compounded by other stressors, each 10,000 feet of altitude doubles the effects of alcohol in the body.

Some effects of various blood alcohol concentrations

0.01 - 0.05 (10 - 50 mg%)	**0.03 - 0.12 (30 - 120 mg%)**	**0.09 - 0.25 (90 - 250 mg%)**	**0.18 - 0.30 (180 - 300mg%)**	**0.27 - 0.40 (270 - 400mg%)**	**0.35 - 0.50 (350 - 500mg%)**
average individual appears normal	mild euphoria, talkativeness, decreased inhibitions, decreased attention, impaired judgment, increased reaction time	emotional instability, loss of critical judgment, impairment of memory and comprehension, decreased sensory reponse, mild muscular incoordination	confusion, dizziness, exaggerated emotions (anger, fear, grief), impaired visual perception, decreased pain sensation, impaired balance, staggering gait, slurred speech, moderate muscular incoordination	apathy, impaired consciousness, stupor, significantly decreased response to stimulation, severe muscular incoordination, inability to stand or walk, vomiting, incontinence of urine or feces	unconsciousness, depressed or abolished reflexes, abnormal body temperature, coma: possible death from respiratory paralysis (450mg% or above)

(TABLE 25)

The effects of alcohol are very much like those of hypoxia in that the more stresses that are involved, the more intense the effect. Part 91.17 of the Federal Aviation Regulations, General Operating and Flight Rules, provides that no person may act as a crew member *(or pilot in command)* of a civil aircraft ***while under the influence*** of intoxicating liquor or until at least 8 hours have elapsed since the last act of alcohol ingestion. The individual pilot must also be alert to sources of ethyl alcohol other than liquor, such as cough medicine, tonics, etc. A good rule to follow is that if you are sick enough to require these substances, you are too sick to fly.

It is also a good idea to allow a reasonable time from ***bottle to throttle*** although eight hours should be sufficient following light indulgence (4 ounces of alcohol). Eight hours is the minimum time allowed by the Federal Aviation Administration for its own pilots before flight can be undertaken following alcohol consumption. Eight hours may not be enough time between bottle to throttle due to the chronic effects of alcohol consumption.

There are several chronic effects of alcohol, such as vitamin, mineral, and protein deficiency; liver impairment, excess carbohydrate levels, alcohol psychosis, etc. The one chronic effect that is most noticeable and poses the greatest danger to you as a crew member is the hangover. Some say that this may be more of a hazard than even mild intoxication. It is more likely that you would find a pilot flying with a hangover, rather than one that was mildly intoxicated. Obviously, neither is condoned, but let's look at the risks of flying with a hangover.

The symptoms of a hangover may not be solely due to alcohol ingestion. Many of the symptoms are due to the activities that accompany drinking. Large amounts of alcohol, along with the increased amounts of gastric acid, will irritate the lining of the stomach. Blood vessels in the brain dilate, which is part of the reason for the headache associated with a hangover. Other factors that intensify the symptoms of a hangover, and usually accompany drinking, are excessive smoking, loss of sleep, and an improper diet. Another factor is dehydration, which occurs by the loss of fluids from the cells of the central nervous system and from the cerebral spinal fluid that surrounds the brain. Loss of this fluid causes tension on the supporting structure of the brain, resulting in a headache. Dehydration can impair one's judgment and cause emotional changes that can seriously interfere with the pilot's ability to perform effectively. It can also lead to, or compound, the effects of disorientation due to its effects on the lower brain, or coordination center. There is evidence that the systems most closely associated to disorientation responses, those of visual and vestibular, may show the effects of alcohol for periods in excess of 24 hours.

℞ DRUGS

We are a society that looks for the "quick fix". As crew members, if you take any type of drug you should know its effects. This applies just as much to over the counter medications as it does to prescription medications. Some people are under the impression that if a drug is safe enough to buy over the counter, without a prescription, then it must also be safe enough to pilot an aircraft while under its influence.

Statistics show that about 80% of all major aircraft accidents, both military and civilian, usually involve human factors. Since the effects of a particular drug can be intensified with altitude it is up to you to be aware of the effects of any medication that you might consider taking before piloting an aircraft. If there is any doubt, you should consult your local Aviation Medical Examiner(AME) as to the possible side effects that a particular medication might have on you, as an aviator.

Self-medicating with over-the-counter medication presents two potential dangers to a crew member. Over-the-counter medications tend to only mask unsafe conditions and make the crew member unsafe. The desired effect of a drug can have undesirable effects on the crew's ability to perform their critical tasks. For example, if you were to take an antihistamine for symptoms of a cold, you would not only experience a relief of the cold symptoms but you would also have undesirable side-effects such as drowsiness, impaired coordination, or even blurred vision. The chart on the opposite page describes some more commonly used, over-the-counter medication along with their side-effects, and possible interactions with other drugs.

As with any other maintenance medication, oral contraceptives should be cleared for use by an AME. The reasons for this are that many of the side effects are unknown and the reaction to the medication varies with the individual. It has also been determined that pregnancy is not compatible with flying because of the possible effects of G-forces, mild hypoxia, and other stresses associated with the flying environment.

OVER THE COUNTER MEDICATION AND DRUGS

	MEDICATIONS	*SIDE-EFFECTS*	*INTERACTIONS*
PAIN RELIEF/ FEVER	**ASPIRIN** Alka-seltzer Bayer Aspirin Bufferin	Ringing in the ears, nausea, stomach ulceration, hyperventilation	Increase effect of blood thinners
	ACETAMINOPHEN Tylenol	Liver toxicity *(In Large doses)*	
	IBUPROFEN Advil Motrin Nuprin	Upset stomach, dizziness, rash, itching	Increase effect of blood thinners
COLDS/FLU	***ANTIHISTAMINES*** Actifed Benadryl Cheracol-plus Chlortrimeton Contac Dimatap Drixoral Dristan Nyquil Sinarest Sinutab	Sedation, dizziness, rash, impairment of coordination, upset stomach, thickening of bronchial secretions, blurring of vision	Increase sedative effects of other medications
COLDS/FLU (cont)	***DECONGESTANTS*** Afrin Nasal Spray Sine-Aid Sudafed	Excessive stimulation, dizziness, difficulty with urination palpitations.	Aggravate high blood pressure, heart disease, and prostate problems

	COUGH SUPPRESSANTS Benylin Robitussin CF/DM Vicks Formula 44	Drowsiness, blurred vision, difficulty with urination, upset stomach	Increase sedative effects of other medications
BOWEL PREPARATIONS	LAXATIVES Correctol Ex-Lax	Unexpected bowel activity at altitude, rectal itching	
	ANTI-DIARRHEALS Imodium A-D Pepto-Bismol	Drowsiness, depression, blurred vision *(See Aspirin)*	
APPETITE SUPPRESSANTS	Acutrim Dexatrim	Excessive stimulation, dizziness, palpitations, headaches	Increase stimulatory effects of decongestants, interfere with high blood pressure medications
SLEEPING AIDS	Nytol Sominex	*(Contain antihistamine)* Prolonged drowsiness, blurred vision	Cause excessive drowsiness when used with alcohol
STIMULANTS	CAFFEINE Coffee, tea, cola, chocolate	Excessive stimulation, tremors, palpitations, headache	Interfere with high blood pressure medications

(TABLE 26) Information taken from "MEDICAL FACTS FOR PILOTS" pamphlet, publication AM-400-92/1

TOBACCO

Smoking has long and short term effects. The long term risks are such conditions as emphysema, heart conditions, and a multitude of cancers. The US Public Health Service has reported that cigarette smokers are 20 times more likely than non-smokers to die from cancer of the esophagus, bladder, and pancreas. Smoking causes a relative deprivation of oxygen to the heart muscle and contributes to circulatory problems by constricting the arterioles. Smoking also irritates the lining of the respiratory tract, causing edema and swelling, and restricts proper respiration. These and other factors could lead to emphysema and other permanent lung damage.

Of the many different potentially harmful substances that one gets from tobacco smoke, three are of particular importance to the flyer. They are carbon monoxide, tars, and nicotine.

Carbon monoxide(CO) constitutes up to 2.5 % of the volume of cigarette smoke and more in cigar smoke. If the smoke of three cigarettes is inhaled at sea level, a blood saturation of 4 % CO may result. One reason for this is that CO will combine with the hemoglobin about 250 times more readily than oxygen. The hemoglobin involved in this combination is not available to carry oxygen to the tissues, producing a degree of hypemic hypoxia, thus reducing individual altitude tolerance.

Tar is the term given to the viscous residue left from tobacco smoke. This is one of the major cancer causing agents. Its primary effect is to cause destruction of the delicate mucous membranes of the respiratory tract. It also interferes with the natural cleansing action of the lungs and impairs proper oxygenation of the blood which reduces tolerance to hypoxia.

Nicotine is an extremely potent drug that acts primarily on nerve and muscle tissue. It is extremely poisonous. The amount found in two cigarettes, if injected directly into the blood stream, could be fatal. Some cigarettes contain 10 to 20 milligrams of nicotine, of which up to 2.3 mg is absorbed if the smoke is inhaled. Up to 1.5 mg is absorbed through the membranes of the mouth if the smoke is not inhaled. A 2.5 mg oral dose of nicotine can cause nausea, and 50 to 60 mg is the lethal oral dose. The person who smokes two packages of cigarettes a day exceeds these amounts, but rarely reports any nicotine effects because of rapid detoxification and the development of tolerance.

There has been certain stigma placed on smoking that tends to make smoking in public socially unacceptable. For this reason many people are opting for the smokeless tobaccos in the form of snuff or chewing tobacco. These forms provide the user with all the detrimental effects of
tobacco, minus the carbon monoxide and toxic vapors. The absence of the CO and toxic vapors is more than made up for by the harmful effects of oral or nasal ingestion of various quantities of tobacco mixed with binding agents and synthetic flavors.

Circadian Rhythm and Air Travel

As statistical studies in long distance flight have shown, most people are sensitive to this travel-produced phase shift, and may experience some discomfort for several days. They become hungry, sleepy, or are awake at the wrong time with regard to the new local time. Their "head clock" and "stomach clock" and elimination system are confused. After transcontinental flights in the U.S., these conditions last from 3-4 days; after transatlantic flights, 5-6 days. Crossing 12 time zones, which leads to a complete reversal of the day-night cycle, may take 10-12 days to re-synchronize. As a general rule, most travelers adjust to a new circadian cycle at a rate of nearly 1 hour per day. Some people feel more easily adjusted after eastbound flights, others after westbound flights, and some when returning to their home time zone with its familiar climate and social order. There are, of course, a few people who are not particularly time sensitive at all.

The problem of circadian desynchrony is especially important for those whose occupations involve time zone changes. Air crews of long distance air routes are in this category. They cross and recross a number of time zones several times a month or even fly around the world once every month. A too-frequent shift of the circadian cycles causes fatigue; this is well recognized by the pilot associations and medical directors of the airlines.

NOTE: *Circadian Rhythms are not to be confused with the fad term "biorhythm" which refers to theoretical cycles in physical, emotional, and intellectual functions(usually about 1 month in duration). Many studies have concluded that this theory has no real value in the aeromedical or physiological training application.*

NOISE AND THE GENERAL AVIATION PILOT

CAUSES OF NOISE

Cockpit noise in light aircraft has been around so long that we all seem to accept it as an inevitable part of flying, like carburetor ice and turbulence.

If noise were merely a nuisance, if all it did was to briefly interrupt our routines, perhaps we could learn to tolerate it.

Of course, it is to be expected that some hearing loss will be experienced by every person during a lifetime, either through aging or through environmental noise. But, for those who fly for either business or pleasure, this problem may occur sooner, unless personal protection is used. Most long-time general aviation pilots have a mild loss of hearing. Many pilots report unusual amounts of fatigue after a particular noisy flight, as well as temporary loss of hearing after flights; and many pilots have difficulty understanding transmissions from the ground.

Noise exposure has harmful effects that are cumulative. Adverse effects on the listener increase as sound intensity and duration are increased. The Occupational Safety and Health Act places strict restrictions on the amount of noise a worker will be subjected to during an 8 hour work shift. No such restrictions, however, are imposed on the general aviation pilot.

At the same time that general aviation aircraft manufactures have developed more powerful engines, they have not given the occupants better noise protection and control, so that today's aircraft are more powerful, yet some are noisier than ever. The levels of sound associated with powered flight are high enough for general aviation pilots to be concerned about participating in continuous operations. In basic terms, propeller-driven aircraft are noisy; helicopters and planes with open cockpits being the noisiest.

Tests conducted at the FAA's CAMI (Civil Aeromedical Institute) demonstrated that all propeller driven, fixed-wing aircraft and all helicopters are sources of damaging noise intensities for the flight crew. The protection afforded by the cockpit is not enough to keep most active pilots from being overexposed. Part of the problem is explained by another CAMI study that showed the fatiguing effects of noise to be increased in a listener, such as a pilot, who is mentally active rather than resting. Since a pilot-in-command cannot rest safely during flight, the noise may affect them more than, for instance, a passenger who is relaxing.

The amount of permanent hearing loss likely to be experienced by a given amount of noise is a function of the susceptibility of the listener, and of the amount of time exposed. A comprehensive investigation would probably show that the most exposed people are aerial-applicators, followed by flight instructors, helicopter pilots, business and commercial pilots, flight attendants, airline pilots, and flight engineers.

PRIMARY SOURCES OF NOISE IN LIGHT AIRCRAFT	
SQUEAKS & RATTLES	Squeaks and rattles may be remedied by welding rather than riveting. However, there still would not be a difference in sound intensity after it was done
EXHAUST	Engine exhaust can be muffled, but this adds weight to the aircraft
PROPELLERS	Propeller driven aircraft predominately produce low frequency noise with the most intense portion of the noise at the pilot's position. The higher speed of propeller rotation will result in a slight upward shift in the predominate frequency range. Prop noise ranges from 89 to 113 dB with an average of 106 dB.
VENTILATION SYSTEM	In light aircraft tested, ventilation noise turned out to be as noisy as all other sources put together. However, if manufactures quieted the system, it would only decrease sound by 3 dB.
AIR TURBULENCE AROUND FUSELAGE	Another source of noise in aircraft is airflow or air turbulence around the fuselage. This is vividly demonstrated when the engines quit during flight and noise is still heard around the aircraft.

(TABLE 27)

Turbulence noise may be reduced by streamlining the aircraft. You can also eliminate a lot of the noise by acoustical treatment of the walls. Rugs, curtains, acoustical tiles are not good for eliminating noise as they only cut down on echo. Acoustical treatments are not effective in reducing transmitted sound. The only solution to the problem is to increase the mass with something like lead blankets. Light aircraft could not be treated in this manner as it is not conducive to flight.

Some type of honeycomb structure might do the same, but it would change the aerodynamic property of the aircraft.

EXPOSURE --vs.-- HEARING LOSS

Different people have different responses to noise. Even for one person, sensitivity may be different in each ear. Because of individual differences in sensitivity, we have to talk about the average case.

In light twin engine planes, the average person will develop significant hearing loss by flying more than 8 hours a week. If you fly 8 hours a week for 10 years in a light twin, you can expect enough hearing loss to begin having trouble understanding speech.

If you fly more than 5 hours a week in a light single-engine aircraft, in 10 years you should expect to have trouble understanding speech.

In open cockpit planes, leaning the head over the side for 30 seconds a week, over a 10 year period could produce significant hearing loss. The Civil Aeromedical Institute has never tested a crop duster pilot who did *not* have a hearing loss and some of those tested had only been exposed for 1.5 years. They fly as many days a year as they can and often are in the air 14 hours a day.

One of the main problems with hearing loss is that it generally occurs very slowly over a period of time. The loss is so slow that aviators are not aware of the problem until speech intelligibility becomes very difficult. By the time this problem is noticed, a permanent hearing loss has probably occurred. Therefore, personal protection early in a person's flying career is the only practical answer to hearing loss in aviation.

Another problem associated with noise is speech intelligibility. Cockpit noise is particularly detrimental to the understanding of speech because the engine and exhaust noises are at their maximum in the same frequency range where speech has its maximum energy. Pilots often report that although the volume or gain control on the receiver is turned all the way up, tower transmissions are garbled or covered up, (masked) by the engine noise. Test at CAMI showed that, under full power take-off conditions, the intelligibility of the tower controller can sometime fall from 100% to zero.

EAR PLUGS

Problems concerning noise in flight are fairly easy to solve. Earplugs or similar hearing protection prevents almost all problems heretofore mentioned. Earplugs or earcaps are devices that are inserted in or pressed against the external ear canal to reduce the effect of ambient sound on the auditory system. Because every ear is unique in shape and size, several approaches to solving the problem of designing adequate earplugs have been taken, As a result, commercially available earplugs may be:

1. PREMOLDED	This includes varieties that are vented and varieties in which a headband presses a cap across the open end of the canal as well as plugs that insert more or less deeply to block the canal opening completely.

2. MOLDABLE	This includes impregnated and non-impregnated and non-porous materials, as well as expandable foams, and putty-like substances. Plain, unimpregnated cotton is useless as a hearing protector, so a commercial ear plug should be used.
3. CUSTOM FITTED	These are either manufactured from an ear impression or the ear impression itself becomes the earplug. Since every ear is unique in shape and size, one might assume that a standard, off the shelf earplug would not protect as well as a personalized or custom-fitted earplug. Intuition says that a custom fitted plug should provide a better, more precise seal within the ear canal, should do so through most of the length of the inserted segment, and should be more comfortable and easier to insert. Although they are generally more expensive, if all the assumptions about comfort, acoustic seal, and ease of use are true, then personalized earplugs would be a bargain despite the higher cost. Tests conducted at CAMI indicated that many of the specifically fitted plugs are not bargains at all; in general, they are more expensive, less comfortable, and less effective than premolded or moldable types. However, custom molded earplugs may be the only answer for those who will not wear earplugs unless they can be convinced that the expense makes them the best available and as such, are a status symbol.

(TABLE 28)

All earplugs are worthless in your pocket or in the glove compartment. Under any circumstances, a poorly fitted noise-protection device is worse than none because it gives the user a false sense of security. Summarily, loose fitting earplugs or headsets are not at all helpful. An earplug that is "so comfortable that I can hardly feel it" is not doing any good. It should not be uncomfortable, but it must fit snugly. The usual technique of wearing only one earphone is not recommended to the pilot because of possible damage to the unprotected ear.

A very common question concerning the wearing of earplugs is "How do you hear what you need to if you wear earplugs?". Hearing protectors work much the same way sunglasses do. If you walk into a dark room with sunglasses on, you bump into things. If you wear them when there is a lot of sunlight, you will be able to see better than you did without them. The same analogy applies to earplugs. If you wear them where its quiet, you will not hear much of anything. If you wear them where it is noisy (say a car running at 40 mph with the windows open) the plugs would be beneficial. You will hear everything you need to hear and you will hear it better. Speech intelligibility is improved tremendously by using earplugs in the cockpit.

When you wear earplugs, people will have trouble hearing you! Without background noise to compete against, you will have a tendency to talk more softly and lower and people will have difficulty hearing you. The background noise is still present to everyone not wearing earplugs, but it will not be as noticeable to you. You probably won't remember this statement until you begin to use earplugs and the tower or your buddy will say, "say again".

The only people who will not hear speech better in noise while wearing earplugs are those who already have a severe high tone hearing loss. These are mostly people who are particularly susceptible to the deafening effects of noise, and who therefore need to be especially careful to protect themselves from further exposure to noise. Wearing earplugs for these people will protect them from any further damage.

Earplugs can be bought for as little as ten cents a pair for wax-impregnated cotton or up to $30 a pair for custom earplugs. The most common varieties range between $.75 and a $1.50 a pair and can be used countless times.

RECOMMENDATIONS CONCERNING EARPLUGS

1. Use earplugs whenever flying.

2. Use ear plugs while using earphones.

3. Be certain that earplugs fit snugly and that headsets are adjusted to cover both ears tightly.

4. Use real earplugs: plain absorbent cotton does not work.

5. Talk a little louder to the passengers and into the microphone; remember that the noise is still there and that one must talk loudly enough to overcome its effects.

6. Check the fit of the ear protector by pressing the earplugs with the forefingers or earmuffs with the palms. If fitted correctly, there will be no change in the amount of sound getting through. If the noise decreases or gets louder, the earplugs are not the right size or improperly fitted. Too much pressure applied manually on the ears may distort the earplugs and the noise may become louder. Earplugs present no problem descending and when cabin pressure increases.

7. Demonstrate the effectiveness of the earplugs to yourself by wearing only one plug during a flight of an hour or more. Immediately after shutting down the engine, remove the plug. The difference in hearing in the two ears will almost make it seem as if the ear that was unprotected during flight is now quite deaf. Of course, it is not. It is only less sensitive because of the exposure to noise and will recover with time.

8. Less fatigue should be noted after a cross-country flight. With less noise, one can fly more comfortably, further, and safer. Try some earplugs, and hear what you are missing.

For additional information, refer to:

"Cockpit noise intensity: Fifteen Single-Engine Light Aircraft" by J.V. Tobias, FAA Office of Aviation Medicine Report 68-21 and "Cockpit Noise Intensity: Eleven Twin Engine Light Aircraft" same author OAM Report 68-25. Also Advisory Circular AC-91-35 is very helpful.

VISION

PRINCIPLES AND PROBLEMS OF VISION

Of the various human sensory equipment, none is more important for flying than the eyes. Good vision, in spite of radar, GCA, and other electronic devices, remains of primary importance in the judgment of distance, depth, and position in flight, and the reading of instruments and maps. For instance, a pilot needs good depth perception for safe landings and take-offs, good visual acuity and color vision for spotting other aircraft, and good night vision if he/she plans on flying at times of low illumination. It is important to aircrew members, then, to know the mechanics of vision and how those mechanics can be influenced in different ways in flight.

ANATOMY AND PHYSIOLOGY OF THE EYE

The eye is an organic camera with an almost inexhaustible supply of film. Both the eye and a camera have a shutter, diaphragm, lens, method of focusing, and film, all arranged in a light-tight container.

Objects that reflect or emit light project an image of themselves on the retina of the eye. The retina is the interior coating of the eye and is located around the sides and to the back. The primary function of the retina is image formation. The retina is the only place in the body where blood vessels can be seen directly. This is done by use of an ophthalmoscope. With this device it is possible for an ophthalmologist to examine the retina and detect vascular changes associated with hypertension, atherosclerosis, and diabetes.

The retina also contains the light sensitive cells known as rods and cones. The rods and cones are visual receptors that are highly specialized for stimulation by light rays. The rods are specialized for vision in dim light. They also allow us to discriminate between different shades of dark and light, and permit us to see shapes and movement. Cones are specialized for color vision and sharpness of vision **(*visual acuity*)**. They are stimulated only by bright light. This is why we cannot see color by moonlight. It is estimated that there are 7 million cones and roughly 10 to 20 times as many rods. Cones are most densely concentrated in the central fovea, a small depression in the center of the macula lutea. The macula lutea, or yellow spot, is in the exact center of the posterior portion of the retina, corresponding with the visual axis of the eye. The fovea is the area of sharpest vision because of the high concentration of cones in this area. Rods are absent from the fovea and macula, and increase in density toward the periphery of the eye.

When information has passed through the photoreceptor neurons it is conducted across synapses to the bipolar neurons in the intermediate zone of the nervous layer of the retina. From here it is passed to the ganglion neurons. These cells transmit their signals through optic nerve fibers to the brain in the form of nerve impulses. Many rods connect with one bipolar neuron, and many of these bipolar neurons transmit impulses to one ganglion cell. This greatly lowers visual acuity, but it permits summation effects to occur so that low levels of light can stimulate a ganglion cell that would not respond had it been connected directly to a cone. The synaptic connections thus contribute much to the difference in visual acuity and light sensitivity.

The axons of the ganglion neurons extend posteriorly, to a small area of the retina called the optic disc. This region contains openings through which the axons of the ganglion neurons exit as the optic nerve. Since it contains no rods or cones, an image striking it cannot be perceived. Thus it is called the ***blind spot.***

REACTIONS TO ILLUMINATION LEVELS AND TECHNIQUES OF SEEING

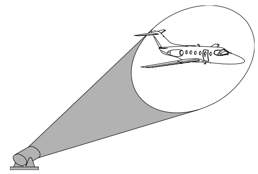
Rods are activated by an amount of light equal to starlight found on a clear night. Cones on the other hand require at least half the intensity of moonlight in order to function. Four factors influencing visual acuity are: size and detail, brightness, illumination, and exposure time.

We have one blind spot where the optic nerve enters the eye. A person does not normally notice this as the visual fields of both the eyes overlap and, in effect, eliminate this optic disc.

At below one-half moon illumination there are two blind spots: the optic disc and the fovea which contains only daylight receptors. An object cannot be seen at night under low light conditions by looking directly at it. By looking 4 - 12 degrees away from an object, it can be seen since the image will then fall on the rods. This technique is called off-center vision and can be developed with practice.

Rods are not always instantly ready for use. The rods contain a substance called rhodopsin, or visual purple, which bleaches very rapidly when exposed to bright light, but the regeneration of this substance can take between 30 to 60 minutes of dark adaptation. During daylight hours, a lack of visual purple makes these cells partly inoperative. If you've ever entered a low illuminated room, such as a theater, from a sunlit area you probably have noticed that your eyes were slow to adapt. Objects that were difficult to see at first became visible over a period of time. This is caused by the progressive regeneration of the photosensitive substances within the cones and rods as the photochemical reaction shifts in the direction of accumulation of these substances.

INSTRUMENT LIGHTING



A number of visual problems arise in night lighting of instruments in the cockpit. The purpose of such lighting is to make the instruments easily readable. Because of other considerations, illumination needed for optimum readability is not always practical. We shall discuss three types of instrument lights.

A. Ultraviolet Flood Lighting of Fluorescent Instrument Markings

The instruments are marked with a paint that is fluoresced with a bluish-green color. This is probably the most unsatisfactory color for preservation of dark adaptation. The ultra-violet lighting system illuminates only the fluorescent instrument markings. Everything else is black. The advantage of this system is the readability of instrument. The disadvantages of this system are: difficulty in keeping the instruments in focus, stray ultra-violet light may reach the eyes and cause fogging of vision, irritation of the eyes and loss of dark adaptation.

B. Red Lights

Both indirect lighting and flood lighting can be provided. The advantage of the indirect system is that light is confined to the instrument face and does not flood the cockpit. The disadvantages of this system include; difficulty in obtaining uniform light distribution over all parts of the instrument, no illumination of knobs and switches located on the panel, and finally, obstructing portions of the dials. Strip lighting will help in identifying knobs and switches.

Flood lighting systems provide red light for the entire instrument panel. These lights are mounted in the cockpit and the reflection from the panel is directed toward the floor. The advantage of this system is that all knobs, switches, and instruments are illuminated. The disadvantages are that large amounts of light are scattered within the cockpit and the difficulty in finding a good place to mount the fixture. Also, Although red light is the most desirable for preservation of dark adaptation, it disturbs our normal color relationship. All color differences are lost. The coloration shown on maps is useless and information printed in red become unreadable.

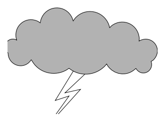
C. White Lights

The latest type of lighting being used in aircraft is low density white light. The advantage of this system is that a more normal instrument picture is presented to the pilot. Readability of instruments is excellent; however, the dark adaptation is somewhat impaired. Regular white light, such as a flashlight, will destroy night adaptation and should be used sparingly. The low density white light can be regulated so that instruments are easily read and the tendency towards disorientation is eliminated. The consensus of pilots flying today is that the white lights are the best.

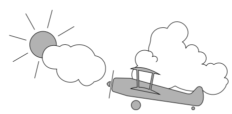
ADVERSE WEATHER LIGHTING

The most common complaints pilots have about anticollision lights is annoyance, with strobe lights being the most irritating. There can be no doubt as to their effectiveness; however, when flying near or through thunderstorms it is recommended that the anticollision light be turned off if it interferes with the pilots orientation. This phenomenon is known as Flicker Vertigo.

THUNDERSTORMS



Lightning flashes encountered when flying near or through thunderstorms create a special lighting problem. To make continued reading of instruments possible under such conditions, a higher than normal instrument lighting intensity is required. This can be obtained easier by using white light rather than red lights.



ALTITUDES AFFECT ON THE EYE

The brain is the main user of oxygen (O_2) being delivered through the body. Since the eyes are an extension of the brain, any decrease in the amount of O_2 being delivered to the brain is quickly felt by the eye. Vision is the first of the special senses of the body to be affected. With increased altitude the extra ocular muscles become weakened and uncoordinated and the range of accommodation is decreased, causing blurred vision and difficulty in carrying out near visual tasks. This impairment can be detected at altitudes as low as 5,000 feet at nighttime and generally around 10,000 feet during the day. For this reason the ***CAMI staff*** recommends the use of oxygen at altitudes of 5 thousand feet and higher at night and at 10,000 feet during the day.

PHYSICAL FITNESS

Research has indicated that the human body, with proper exercise, nutrition, and rest, has the potential to live 120 years. However, due to stress, poor nutrition, and improper exercise, the average life span for an American is 72 years. Of course, if you do all the right things, there is no guarantee that you will live for one and one-fifth of a century, but, it should help to ensure a long, prosperous, and vigorous career.

GETTING STARTED

The first step in getting yourself physically fit is to get a complete physical examination. Since pilots must maintain a current Medical Certificate, you may feel that is your "O.K." to start an exercise program. But, if you fly under a class II or class III Medical Certificate, you may want to consider getting a more comprehensive examination. Always tell your doctor your intention of starting an exercise program and get advice on what the doctor thinks would be the best approach.

AN EXERCISE PROGRAM

Exercise is generally divided into two distinct classifications:

AEROBIC Aerobic exercise will target the cardio-vascular system. The objective is to raise the heart and breathing rate over a relatively long period of time.

ANAEROBIC Anaerobic exercise will target the muscular-skeletal system. The objective is to increase muscular strength and tone through resistance-type training

TYPES OF AEROBIC EXERCISES

The following table of exercises is based in the order of preference by exercise physiologists based on their effectiveness, impact on joints, safety, and timeliness:

AEROBIC EXERCISE	Nordic Skiing (Nordic Trac)
	Walking
	Swimming
	Cycling
	Running
	Aerobic Dance

Of course, when deciding which exercise is best for you, you should consider:

SAFETY A person should know his/her limitations. Never push yourself to the point of exhaustion. Start out slow and gradually work your way up to ***your*** next level. If you use any type of equipment in your exercise program, ensure you know how to use the equipment properly. If your program involves swimming, always have a partner or a lifeguard present in case there is trouble.

TIME Finding time to exercise may be your biggest challenge. If you choose to exercise early in the morning, make sure it doesn't interfere with your sleep. If you cut your sleep time, you can never fully recover from the fatigue and stress of the program. If time is short, you will need to find an exercise that gives maximum output in a short period of time (again, within the confines of your own limitations). Nordic, or cross-country skiing seems to be the exercise that most exercise physiologist agree on. With Nordic-type exercisers, this can be done within your own home, and at your own time and rate.

EXPENSE What you are willing to spend is another limitation to the exercise you want to perform. Most gyms, or, fitness centers, will have an aerobics program. This of course will cost you a membership fee. Most fees tend to range from $20 to $50 per month depending on the facility. Nordic type exercisers range in cost from about $100 to $1000. This category is really dependent on additional equipment, but, keep in mind that many of these exercises do not need gyms, fitness centers, or equipment. And, they are absolutely free.

ANAEROBIC EXERCISE

There is only one true form of anaerobic exercise: weight lifting. Weight lifting is a highly effective form of exercise. It places stress upon specific muscle groups that the trainee desires to train. The following table breaks weight lifting down into two basic categories:

MACHINES Machines used in weight lifting make it very simple. You simply associate a machine with the muscle group (arms, legs, chest, and back) to be exercised. The biggest advantage of machines is safety. If you exercise to the point where you can no longer perform the exercise, simply allow the weight to come down, and then you can rest and continue the exercise or call it quits. This is in distinct contrast to free-weights. The biggest disadvantage with machines is their effectiveness to stress the muscle group properly. Because the machine is balancing and controlling the weight for you, this will also take some of the stress off the muscle group.

FREE WEIGHTS Free weights are the most efficient form of weight lifting. Unlike machines, free weights require not only that you lift the weight, but balance and control it as well. Because of this difference, not only will it stress the target muscle group, it will also stress the muscles that surround and support that particular group. Free-weights require training and experience to lift properly. If the lift is done improperly, it can cause the muscle to be damaged. Another disadvantage of free-weights compared to machines, is that you should never lift alone. If your muscles fatigue to the point of failure, the weight can come down abruptly and cause harm to your body and ego.

Anaerobic exercise requires training and supervision. For this reason, a gym or fitness center will be the best environment in which to conduct this type of exercise program.

DEVELOPING A PERSONALIZED PROGRAM

The best exercise programs for pilots would be one that takes advantages of an aerobic and anaerobic exercise program. A circuit weight lifting program (where machines are set up so that all muscle groups are exercised as you use each of the various machines), coupled with a good aerobic exercise is most effective. Keep in mind that, if you are an aerobatics pilot, research has shown that by engaging in a rigorous weight-lifting program, that you will be more resistant to the Gz forces encountered during maneuvers. Although an aerobic exercise will make you less resistant to Gz forces, most ordinary pilots would benefit more from a good aerobic program with an occasional anaerobic session.

TRAINING FREQUENCY

How often should you train? That is a very personal question. It depends on your current fitness level and the your ability to recover from the fatigue brought about by the exercise. You will have to do a lot of experimenting to find the right frequency. The best way to judge it is to see how you feel the following morning after the exercise session. If you find that you are very fatigued in the mornings, you must do one of three things:

1. INCREASE THE REST PERIOD BETWEEN EXERCISE SESSIONS.	This can be accomplished by increasing the amount of sleep you get following exercise. Or, increase the number of days between exercise.
2. DECREASE THE EXERCISE INTENSITY.	Decrease the time spent exercising. If you are using free-weights, decrease the amount of weight you are using.
3. OR DO BOTH	Decrease the exercise intensity and increase sleep and days between exercise sessions.

As an average, exercising 3 days a week with at least 24 hours between session will probably work out to be a "happy medium" for most pilots.

SURVIVAL

At any time, a pilot may face the problems of human physiology at altitude. Hypoxia, decompression sickness, and trapped gases are potential companions on all flights. Through education and training, a pilot can learn to recognize and prevent these problems. Another serious threat to a pilot's well being doesn't accompany high altitude; it occurs on the ground. After an emergency landing or ditching, a pilot is faced with the problem of surviving until rescue arrives.

PSYCHOLOGICAL ASPECTS

It has been said that survival is 5% physical stress, and 95% mental stress. Most of the mental stress can be curtailed through a ***positive mental attitude***. This could be described as a positive outlook on any situation. However, there are many obstacles to a positive mental attitude while trying to survive. The first obstacle takes place even before the emergency landing. It can be best summed-up as, "It can't happen to me." A person with this attitude will never prepare for a survival episode, because they're not willing to admit to themselves that this is a possibility. Most denial, such as this type, stems from fear. A knowledge of what you will be facing in a survival episode may help you to gain a better understanding of what exactly may be causing this fear.

Some of the common obstacles that survivors will possibly face are;

PAIN Pain is usually a result of injury. It is your brain's way of telling you that something is wrong. Pain is purely mental, and therefore can be controlled by the brain. If you treat the injury, and the pain persists, keep your mind busy and off the pain.

INJURY AND ILLNESS Injuries must be treated immediately. In a survival environment, they will be very prone to infections. Infections can cause fever making it very hard to think and mentally respond to survival obstacles.

TEMPERATURE EXTREMES Being extremely hot or cold will not only make you miserable, it can also be deadly. The human body can withstand extreme temperature variations externally, but not internally. As body temperature rises or falls, it will first affect the mind and eventually, deteriorates a positive mental attitude.

THIRST As the body's water supply dwindles, you will become thirsty. As the body further dehydrates, body temperature rises and the blood thickens. This deprives the brain of precious oxygen and makes your ability to think clearly very difficult.

HUNGER As creatures of habit, we tend to eat at certain times of the day. When you are surviving and food is scarce, and it's time for breakfast, lunch, and dinner, your body is expecting food. The hunger pains you experience come from the brain, and therefore, can be mentally controlled.

FATIGUE The stress of surviving will be felt physically and especially, mentally. Take frequent rest breaks and relax. This will allow you to unwind and will refresh you both physically and mentally.

BOREDOM Boredom has no place in survival. There should always be something a pilot can do to better the situation.

LONELINESS Companionship is a basic need for the human species. Again, keeping the mind busy will help you to cope with this problem.

Probably the most important psychological factor of survival is the ***will to survive***. Without a will to survive there can be no survival. A person must want to survive. You must have something in your life that is greater than the sum of your fears. For many, family is a strong driving force. The love of life, or maybe the fear of death, can make a person overcome a no-win situation and survive. Most humans are born with a will to survive. However, due to the "creature comforts" of life, and being part of a push-button society, a will to survive can be weakened. You can't buy a will to survive, but you can reinforce the one you have. One of the best ways to do this is to pack a personal survival kit and carry it with you on every flight. This does two essential things for the survivor. First, it will give the essential items you need for surviving. And last, and probably most importantly, it will strengthen your will to survive. How? By doing this, you have just admitted to yourself that you can possibly, at some time, find yourself in a survival episode. By admitting this fact, you are beginning to face your fear concerning survival after an emergency landing.

PACKING A PERSONAL SURVIVAL KIT

When packing a personal survival kit, there are several categories of equipment that should be included. Such as;

FIRST AID A first aid kit should include at least
- 2 compress bandages (4"x 4")
- 2 compress bandages (2" x 6 yards)
- 1 roll athletic tape
- 1 small bottle of methiolate
- 5 adhesive bandages
- Personal medications

SHELTER The primary shelter that you take with you on the aircraft is your clothing. Try not to dress for the cockpit environment, but for, the potential survival environment. Other shelter to consider would be something to further insulate the clothing you already have. An 8 bushel trash bag works very well to insulate your clothing from the wind and wet.

WATER PURIFICATION Water purification tablets will make it easy for you to purify water. Boiling water for 5 minutes will also purify water.

FIRE STARTING Fire is a survivor's best friend. It will give you a source of light, heat, protection, and signaling, and will sanitize food and water. Starting a fire in the wilderness requires a great deal of skill. This skill must be nurtured through practice and not from just reading a book. There are several fire starting devices that may be purchased for your kit. But none are as easy and effective as just simple matches; take precautions to keep them water proof .

FOOD Food has a low priority in survival. The average person can survive over 3 weeks without food. If food is placed in the kit, ensure that it is the type that won't spoil.

SURVIVAL TOOLS The best tool for survival is a good knife. There are several types on the market to choose from. Make sure that the knife is sharpened before using it. Also, check out some of the multi-tools on the market. These tools will give you a variety of functions in a small package.

SIGNALING A signaling device that should be included in all kits is a signal mirror. Considered to be the best all-around signaling device, mirror flashes have been spotted over 20 miles away.

When putting a personal survival kit together, try to keep it as compact as possible. Also, it would be a good idea to keep the kit in close proximity to the body at all times. After an emergency landing, you will need to evacuate the aircraft as quickly as possible. If your personal survival kit isn't handy, you may not have a chance to get it out of the airframe. A very good container to pack your survival gear in is a fanny pack. These packs will keep your survival gear next to your body at all times. So, when you leave the aircraft, it will also.

Preparing for survival has to be accomplished on a physical and psychological level. Preparing for the physical hardships of survival is relatively easy. You can pack survival gear to cope with just about any emergency. But, there is nothing you can pack in a kit to help you mentally. As you are flying along, look below and ask yourself;" What would I do if I had to make an emergency landing at this very moment?". One thing that would help you in that situation would be to evaluate your situation. Take a look at your basic needs. And then, devise a plan to meet those needs. A checklist would be outstanding for this situation. A checklist will put all your tasks in black and white. It will give you an basic idea on how to survive. But, probably most important of all, it will allow you to start to think and plan everything logically. This will go a long way in the fight against fear, anxiety, and panic.

Here is a simple checklist that you can use in any survival environment:

STAY NEAR THE AIRCRAFT	Always stay near the airframe. When rescue parties are launched, they will be looking for the crash site and not for a survivor walking for help.
IF TEMPERATURES ARE EXTREME, SEEK OTHER SHELTER	When the temperature gets extremely hot or cold, the aircraft does not make a suitable shelter. If extremely hot, look for any shade, or create some by erecting an overhead shelter.
LIGHT A FIRE	Lighting a fire will do many things for a survivor. Most all of the things are good, but a fire can also become an enemy. Be careful.
PROCURE WATER	Life expectancy without water, under extreme conditions, can be as short as 3 days. Procure water before you become thirsty and make sure all water is purified before consuming.

READY SIGNALING DEVICES Signal mirrors, flares, radios, rescue codes should be used immediately. Always familiarize yourself with signaling devices (especially radios and flares) before using.

REST Try not to push yourself to the point of exhaustion. In this state, you're not very good to yourself or crew members. Take frequent rest breaks and allow yourself to rest both mentally and physically.

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