Oxygen Course Notes

A short course for
high fliers

Presented to the
Piako Gliding Club

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8 August, 1999.

Oxygen course notes

Aim

The aim of this course is to give an understanding of the following as they relate to glider operations at altitudes above 10,000':

1. the physics of the atmosphere
2. the physiology and anatomy of the body
3. the signs, symptoms and effects of hypoxia
4. the principles and operation of supplemental oxygen systems
5. special considerations of high altitude glider operations
6. incorporation of the above factors into a method for ***SAFE*** glider operations

PHYSICS OF THE ATMOSPHERE

Definition - Envelope of gases surrounding the earth

Functions - Life support

Thermal environment

Weather patterns

Barrier to solar radiation

Sound propagation

Aerodynamic support

ISA ~ International Standard Atmosphere

Theoretical or ideal atmosphere as basis for comparison

Composition - Oxygen 21 %

Nitrogen 78 %

~ other 1 % (Argon, inert gases, carbon dioxide)

ISA is dry but in reality up to 5 % water vapour also

Pressure - Caused by collisions between gas molecules

Pressure at sea level in ISA is:

76OmmHg
29.92 inhg
1013.2 hPa
14.7 psi

Falls exponentially with altitude

Halved at 18000 ft

Quarter at 33000 ft

One hundredth at 100000 ft

Water boils at 63000 ft at body temp.

Greatest pressure change is close to sea level

Temperature - ISA falls at 2 C/100Oft up to tropopause

Actual lapse rate varies with weather (from 1.5~3 C/100Oft)

Boyle's Law - Pressure and Volume inversely proportional (P x V = constant)

<u>Therefore GASES EXPAND AT ALTITUDE</u>

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<u>PARTIAL PRESSURE OF OXYGEN</u>

The quantities of a gas at various altitudes, expressed in percentages of the atmosphere, has little significance. Percentage represents the relative volume of a gas and not its molecular *concentration. Molecular concentration, or partial pressure, determines the availability of the gas to the body.*

The partial pressure of a gas, in a mixture of gases not interacting with one another, is equal to that pressure that the particular gas would exert if it alone occupied the space taken up by the mixture (Dalton's Law of Partial Pressure).

The total pressure of a mixture of gases is the sum of the pressure of the individual gases composing the mixture.

<u>*This means that as the total pressure reduces, the partial pressure of oxygen also reduces. This also means that if we increase the % of oxygen the patrial pressure of oxygen will increase and enable adequate oxygenation of our bodies.*</u>

<u>ANATOMY & PHYSIOLOGY</u>

<u>GAS IN THE BODY</u>

Four sites

Lungs

<u>Digestive tract (gut)</u>

<u>Middle ear</u>

<u>Sinuses</u>

<u>Lungs</u> - System of branching tubes leading to air sacs (alveoli)

<u>Alveoli allow gas exchange with capillaries</u>

<u>Gas expansion only a problem if rapid climb and some of breathing tubes obstructed eg asthma, chest infection.</u>

<u>Gut</u> - Long, easily distensible tube

<u>Usually no problem but high altitudes can cause pain or fainting</u>

<u>Problems more likely with rapid climbs. Pays to avoid fizzy drinks, gas-producing foods before flying.</u>

<u>Middle ear</u> - Between eardrum and organ of hearing cochlea)

Contains gas and 3 bones

Eustachian tube connects to throat

Designed to equalise pressure either side of eardrum

<u>Problems always occur on descent</u>

On ascent gas expands and escapes

On descent gas contracts and tube collapses

<u>Need to actively open tube: swallow, wiggle jaw, yawn, Valsalva If flu/cold opening of tube is swollen and may be unable to vent.</u>

If unable to clear, pain, bleeding and possible eardrum rupture

Oxygen ear (following flight on 100% oxygen)

<u>Sinuses -</u> Gas containing cavities to lighten skull

Also resonate voice and produce mucus for trapping dust
Located beside and above nose, connected to nose by tubes
May cause problems on ascent or descent
If opening completely blocked pain on ascent
If partially blocked gas escapes on ascent and pain on descent

Pain is severe and mistaken for toothache

May get bleeding into sinus
Much more likely if flu/cold/hay fever

Teeth - Normally no gas
Recent dental work may leave trapped gas
Expansion could eject filling
With dental decay in root of tooth, bacteria may produce gas
Expansion of gas causes pain

CARRIAGE OF OXYGEN

Respiration
Every cell in body requires oxygen
Oxygen + Glucose ----- > ENERGY + Carbon Dioxide + Water
Oxygen not stored; continuous supply required
Without oxygen cells unable to carry out functions
Cells with the greatest requirement are those most active

Oxygen breathed in from atmosphere
Warmed, humidified, filtered in nose
Through to alveoli of lungs
Oxygen passes in to blood, C02 out of blood into alveoli
In bloodstream oxygen carried by haemoglobin (Hb)
Normally 97% of Hb carries oxygen

OXYGEN TRANSPORT

Haemoglobin is the oxygen-carrying agent of the blood. Oxygen must diffuse from a gaseous state to a dissolved state to combine with the haemoglobin.
The solubility of a gas, *and its partial pressure*, greatly influences its diffusion characteristics. Carbon dioxide is about 25 times more soluble than oxygen in pulmonary tissues and fluids and its capacity for diffusion is about 20 times greater than oxygen. This means that hyperventilation will rapidly remove CO_2 from the blood reducing its pH. In other words rapid breathing will change the blood chemistry faster than the kidneys can cope with and will produce symptoms that may be mistaken for hypoxia.

The body requires haemoglobin saturation's of 87-97 % and arterial oxygen at 60-100mm Hg (millimetres of Mercury) in order to function normally. Below this level the body is *hypoxic*.

The standard pressure at sea level is 760mm Hg. Since oxygen comprises about 21 percent of the air, we would expect the dry air oxygen partial pressure in the lungs to be 159.6mm Hg (760 times 21 percent), but through physiological processes, the partial pressure of oxygen in the arterial blood is normally about 100mm Hg.
Air inhaled into the lungs enters small air sacs (alveolus) where the exchange of oxygen and carbon dioxide occurs. When the partial pressure of the oxygen is higher than it is in the blood, oxygen molecules are picked up by the haemoglobin molecules. This haemoglobin saturation is approximately 97 percent at sea level.
The atmospheric pressure decrease at 10,000-foot altitude causes 523mm Hg ambient air pressure resulting in 87 percent haemoglobin saturation and 61mm Hg arterial oxygen.
At 15,000 feet (429mm Hg) the haemoglobin saturation is 80 percent (we need 87-97 percent for normal functioning), and arterial oxygen is 44mm Hg (the body requires 60-100mm Hg.).

Minimum oxygen in alveoli 54mmHg to prevent hypoxia
This is equivalent to breathing air at 1000Oft

HYPOXIA

Hypoxia, is simply a lack of oxygen at the tissue level of the body due to a decreased partial pressure of oxygen in the inspired air. It's advanced stage produces euphoria, a false sense of well being, that renders a person incapable of understanding that anything is wrong. Hypoxia may lead to death.
Like a glider, the human body has a service ceiling. Use supplemental oxygen to avoid exceeding your service ceiling.
A syndrome, anoxia, meaning literally "without oxygen," is occasionally and erroneously used to denote a deficiency, rather than a lack of oxygen in the tissues. This term is not used for flight below 55,000 feet. Even in acute cases the tissues are never entirely without oxygen.

CAUSES

Hypoxia may be caused by climbing to an altitude where the body is susceptible to a loss of arterial oxygen below that required by the body.
Equipment failure, either a mechanical malfunction or exceeding the capabilities of the design of a supplemental oxygen system, can lead to hypoxia.
When a pilot inhales air at high altitudes, there isn't enough oxygen pressure to force adequate amounts of this vital gas through the membranes of the lungs into the bloodstream so that it can be carried to the tissues of the body.
At sea level, a healthy person can extract enough oxygen from the air to continue normal activities. Above 8,000–9,000 ft (2,400–2,700 m), however, problems related to hypoxia begin to appear. Because the air is less dense, it offers less oxygen per breath of air inhaled—although oxygen and nitrogen are still mixed in a 20:80 ratio. At about 10,000 ft (3,048 m), the blood can still carry oxygen at 90 percent of its capacity. At this altitude, the flight performance of a healthy pilot is impaired only after some time*. At 14,000 ft (4,300 m), the pilot may become appreciably handicapped. From 18,000 ft (5,500 m) and beyond, exposure to environmental air quickly causes total collapse and inability to control the glider.*

Symptoms of Hypoxia

Hypoxia symptoms are diverse, varying from person to person,
depending on variables such as absolute altitude, rate of ascent, duration at altitude, ambient temperature and physical activity.
Individual factors include: inherent tolerance, physical fitness, emotionality, and acclimatisation.
It is felt that if a person has attended hypobaric training and has determined his individual character for the onset of hypoxia, that identifying character remains the same.
Regardless of acclimatisation, endurance, or other attributes, every pilot suffers from hypoxia when exposed to inadequate oxygen pressure.

TYPES

Histotoxic Hypoxia –

This form results from tissue poisoning such as from alcohol, narcotics, and certain poisons. The utilisation of oxygen by the body tissues is interfered with and the tissues are unable to metabolise the delivered oxygen.

Hypemic Hypoxia –

The inability of oxygen to bind to the haemoglobin, as a result of a large blood loss, chronic anaemia (decreased haemoglobin content), or the forming of compounds with haemoglobin (carbon monoxide, nitrites, sulfa drugs) that reduces the amount of haemoglobin available to form oxyhemoglobin.
SMOKERS BEWARE: Carbon monoxide has an affinity for the blood 20 times greater than oxygen. Given a choice between carbon monoxide and oxygen, the haemoglobin will choose the carbon monoxide. A regular smoker has a physiological altitude of 3,000 to 8,000 feet while at sea level.

Hypoxic Hypoxia –

This is a lack of oxygen as a result of a high altitude (decreased oxygen pressure) or by conditions that prevent or interfere with the diffusion of oxygen across the alveolar membrane (asthma, pneumonia)

Stagnant Hypoxia –

This is attributable to a malfunction of the circulatory system resulting in a decrease in blood flow.

Causes include high g-loading, exposure to extreme hot or
cold temperatures, or by shock.

Hyperventilation Syndrome –
Over-breathing due to excitement or stress. Cyanosis – Blue discolouration of the skin.

STAGES OF HYPOXIA

INDIFFERENT STAGE –
The only adverse effect is on dark adaptation. (Night vision)

COMPENSATORY STAGE –
Physiological compensations provide some defence against hypoxia so that the effects are reduced unless the exposure is prolonged or unless fright or exercise is experienced. Respiration may increase in depth or slightly in rate, and the pulse rate, the systolic blood pressure, the rate of circulation, and the cardiac output increases.

DISTURBANCE STAGE –
In this stage the physiological compensations do not provide adequate oxygen for the tissues.
Subjective symptoms may include fatigue, lassitude (state of exhaustion), somnolence (drowsiness, sleepiness), dizziness, headache, breathlessness, and euphoria.
Objective symptoms include:
Special Senses **–**
Both the peripheral and central vision are impaired and visual acuity is diminished. Extraocular muscles are weak and incoordinate. Touch and pain are diminished or lost. Hearing is one of the last senses to be impaired or lost.
Mental Processes –
Intellectual impairment is an early sign and makes it improbable for the individual to comprehend his own disability. Thinking is slow. Calculations are unreliable. Memory is faulty. Judgment is poor. Reaction time is delayed.
Personality Traits **–**
There may be a release of basic personality traits and emotions as with alcoholic intoxication. (Euphoria, elation*, pugnaciousness, overconfidence*, or moroseness).

CRITICAL STAGE –
In the critical stage consciousness is lost. Death follows shortly.

PREVENTION

Objective is to never expose to equivalent of above 10000-ft partial pressure oxygen.
Stay below 10000 ft   Can't ascend above weather. Can't cross sink or geographic barrier.

Hypoxia tolerance impaired by -

Rapid ascent rate

+ G Forces
Exertion
Dehydration
Cold (may bring on asthma)
Pain
Alcohol or Medication
Anxiety

Fatigue or illness
Increasing Altitude
Hangover
Stress
Poor fitness
Smoking
Improved by acclimatisation

Time of Useful Consciousness

Time during which able to recover unassisted

~ Gives measurable index of severity of hypoxia

Altitude	Typical TUC Resting	TUC Exercising
18000 ft	15 min	10 min
25000	3 min	2 min
30000	-75 sec	45 sec
45000	*20* sec	12 sec
56000	*12* sec	12 sec

HYPOXIA CAUSES HYPERVENTILATION - Early response to hypoxia is increased depth and rate of breathing.

Therefore EARLY SIGNS OF HYPOXIA ARE THOSE OF HYPERVENTILATION .HYPOXIA in the air ~ Treatment: 100% ox gen and descend

HYPERVENTILATION in the air - Treatment: 100% oxygen and descend

UNEXPLAINED SYMPTOMS in flight- Treatment: 100% oxygen and descend

HYPOXIA

Altitudes and effects

UP to 10000ft Few symptoms if healthy but night vision reduced Slight effects on mental ability. Symptoms can be marked if unhealthy

10000~15000ft

Few signs at rest if healthy. Easily fatigued, some hyperventilation symptoms Mental function, memory, concentration poor Reduced visual acuity and colour vision

15000-2000Oft

Incoordination, fatigue
Hyperventilation symptoms and cyanosis
Slowed thought processes, poor judgment
Loss of self-criticism
Tunnel vision, blurring of vision

Above 20000ft

Marked physical impairment

Mental performance at simple tasks poor
Drunken behaviour
Loss of consciousness if not acclimatised

Oxygen Paradox –
Temporary worsening after oxygen restored 15-30 seconds only. Probably due to constriction of dilated arteries in brain

DEHYDRATION and LOW BLOOD SUGAR
This is an additional hazard for glider pilots. We are often on the point of dehydration and breathing dry aviation oxygen at altitude only makes this worse. It IS important to keep well hydrated.

Hyperventilation.

The symptoms of hyperventilation and hypoxia are somewhat related and often are misunderstood. Hyperventilation, or over breathing, is a disturbance of respiration that may occur in individuals as a result of emotional stress, fright or pain. The respiratory centre of the brain reacts to the amount of carbon dioxide found in the blood stream. When you are in a physically relaxed state, the amount of carbon dioxide in your blood stimulates the respiratory centre and your breathing rate is stabilised at about 12 to 20 breaths per minute. When physical activity occurs the body cells use more oxygen and more carbon dioxide is produced. Excessive carbon dioxide enters the blood and subsequently the respiratory centre responds to this, and breathing increases in depth and rate to remove the over supply of carbon dioxide. Once the excess carbon dioxide is removed, the respiratory centre causes the breathing rate to change back to normal.

To check for hypoxia or hyperventilation:

1. Check your oxygen equipment immediately. See if there is oxygen and the flow is at the proper rate for the altitude you are. The use of Nelson flow meters will verify if your system is working properly.
2. After three or four deep breaths of oxygen, the symptoms should improve markedly if the condition experienced was hypoxia. (Recovery from hypoxia is extremely rapid).
3. If the symptoms persist, you should consciously slow your breathing rate until symptoms clear and then resume your normal breathing. You can also breath into a bag, or talk aloud to overcome symptoms of hyperventilation.

Under conditions of emotional stress, fright or pain, the pilot's lung ventilation may increase, although the carbon dioxide output of the body cells remains at a resting level. As a result, he "washes out" carbon dioxide from his blood.

The most common symptoms are dizziness; hot and cold sensations, tingling of the lips and hands, legs, and feet; rapid heart rate; blurring of vision; muscle spasms; sleepiness; and finally unconsciousness.

After becoming unconscious, the breathing rate will be exceedingly low until enough carbon dioxide is produced to stimulate the respiratory center. Hyperventilation occurs as a result of the body's normal compensatory response to hypoxia. However, excessive breathing does little good in overcoming hypoxia.

Several aircraft accidents have been traced to probable hyperventilation. It is recommended that you induce hyperventilation by voluntarily breathing several deeps breaths at an accelerated rate (not while flying). You will begin to get some of the symptoms mentioned. Once you experience several of these symptoms, return to your normal rate of breathing. After you become familiar with the early warnings your body gives you, the likelihood of an accident caused by hyperventilation will be reduced. Caution: Do not hyperventilate while alone or in a standing position. You may fall and injure yourself.

DECOMPRESSION ILLNESS

Henry's Law –

Some of gas in contact with a liquid is dissolved in the liquid. Amount dissolved depends on (partial) pressure of gas.

Therefore nitrogen is dissolved in body fluids at sea level

At altitude nitrogen comes out of solution but can form bubbles

Bubbles harmful only at altitudes above 1800Oft (unless diving)

Symptoms of DCI

Joint pains (Bends)

Skin itch and rash (Creeps)

Cough, chest tightness, breathing problems (Chokes)

Unco-ordination, weakness, paralysis, collapse (Staggers)

Risk increased by - Remaining at altitude for prolonged periods

Rapid ascent

1. Multiple ascent
2. Cold
3. Exercise at altitude
4. Obesity
5. Injury
6. Age
7. Fatigue, Dehydration, Illness, Alcohol
8. Hypoxia
9. Diving before flying

Treatment in air - As for hypoxia. 100% Oxygen, Descend, also keep warm/still

After landing need 100% oxygen and/or recompression

Fortunately glider pilots do not tend to suffer from decompression sickness, probably because we climb slowly and have frequent descents which allow excess nitrogen to be blown off. (no pun intended)

Supplemental oxygen

maintains sub 10,000' pp O2
Hypoxia may be prevented with the use of supplemental oxygen at altitudes specified by regulation (maximum 30 mins above 10,000' but below13,000' provided oxygen is available and the pilot is rated.)
An immediate descent below 10,000-feet msl will provide rapid recovery from hypoxia's early symptoms.
Some susceptible persons will require supplemental oxygen at altitudes lower than those specified by regulation.

PRINCIPLES AND OPERATIN OF SUPPLIMENTAL OXYGEN SYSTEMS
Work on the principle of increasing the partial pressure of oxygen by adding oxygen to the inhaled air. This will increase the % of oxygen and therefore the % of the total ambient pressure due to oxygen will increase. (Increased partial pressure 02)
Obviously at some point the total ambient pressure will reduce to below the minimum partial pressure of oxygen needed to avoid hypoxia, at this point even 100% oxygen with a partial pressure equal to the ambient atmospheric pressure is inadequate. This happens at 35,000'. From this point on you would need to pressure breathe 02. Pressure suits, pressurised suits, pressure breathing and pressurised cockpit are all outside the scope of normal gliding. Even though a gliders oxygen system is capable of keeping you well oxygenated up to 35,000', at these sorts of altitudes the risk of decompression sickness increases. The higher you go the worse are the consequences of an O2 equipment failure, or airframe/canopy problem. (See T.U.C. table)
All oxygen systems that work by adding oxygen at ambient pressures will consume oxygen at a greater rate the higher you fly.

Types of Oxygen Systems

There are several types of oxygen systems commonly found in general aviation aircraft:
1. Constant flow. 2. Altitude adjustable. 3. Altitude compensating. Each type has advantages and disadvantages.

Constant Flow Systems.
The most common and lowest cost system found in general aviation is the constant flow type. The basic system includes three parts: the cylinder(s), regulator, and manifold system.

The cylinder is common to all systems. It can be made from steel, aluminium, or composites. The tank pressure is usually less than 2,200 pounds per square inch (psi). The regulators which step down the pressure from 2200 psi to 20-75 psi can be attached separately from the cylinder(s) or directly screwed onto the cylinder. Most regulators are of the diaphragm type. They typically hold a constant output pressure between 20 and 75 pounds, depending on the manufacturer, from either a full cylinder to one that is almost empty. A manifold system is built into the regulator for portable systems. For built-in systems there is a manifold system installed in the aircraft. The manifold system operates at the 20-75 pound pressure, and not the 2,000+ pounds cylinder pressure.

The constant flow type provides the same output pressure or flow regardless of altitude. There is virtually no maintenance required. It is low in cost and well as low in weight. The regulator output is typically 2.5 to 3.0 litres per minute at a regulated line pressure of 25 to 75 pounds. The output is controlled by a small orifice in the regulator itself or most commonly done by the connector going into the manifold system. Many portable systems are also of the constant flow type.

The disadvantage of the constant flow system is that there is a waste of oxygen at lower oxygen altitudes. The system typically provides the pilot a flow of 2.5 litres per minute. This is the correct amount of oxygen at 25,000 feet. However, if the aircraft were only at 15,000 feet, only 1.5 litre's per minute are required. There is a waste of 1 litre per minute of oxygen. The excess oxygen used has no serious medical effect other than drying out your nose quickly. Obviously, however there is an economic disadvantage.

Altitude Adjustable Systems.

An altitude adjustable oxygen system is similar to the constant flow system except there is an adjustable control to set the necessary flow. This adjustment is accomplished by turning a control knob so a reading on a gauge, calibrated in altitude, is the same as the aircraft's altimeter setting. There is a significant saving in oxygen, since you are not wasting the excess flow of oxygen. The military surplus A8A regulators of the altitude adjustable type are commonly used in many gliders.

The red/green indicator is commonly used to show flow. As previously mentioned, this doesn't tell you that the system is working properly.

Altitude Compensating Systems.

The altitude compensating system is similar to the altitude adjustable systems except that the adjustment is done automatically instead of manually setting the flow rate to an altitude gauge. Some portable systems have this feature. The systems work quite well in the automatic mode. There are again disadvantages to this type of system. Some systems do not turn on or provide any oxygen until the system is at 8 to 10,000 feet. If you want oxygen at a lower altitude, you are out of luck In addition, usually there is no actual flow meter available to indicate if the automatic flow control device is working properly, this is done with a LED or warning buzzer if flow is interrupted. The disconnection of oxygen tubing may also activate this warning buzzer.

All systems will have some form of oxygen regulator. The most common system, often panel mounted will be combined with a contents gauge (A8A). With this system you need to adjust the altitude scale manually to match your altimeter reading (hopefully accurate). As you increase your altitude the flow of oxygen will increase. *More convenient are the automatic regulators with built in barometers. These will adjust the oxygen flow automatically depending upon the mode (day or night) setting if present.*

CONSTANT FLOW OR ON DEMAND

Constant flow is just what it says, continual delivery of oxygen probably into a mask with a bag attached. You may need to prime the bag by turning the regulator up to a higher altitude initially, to avoid sucking on an empty bag. These systems will use more oxygen than an on demand system. The on demand systems sense you taking a breath and deliver a bolus (pulse) of oxygen which is taken directly into the lungs rather than into a bag. As the oxygen is rich in the first part of the breath these systems work well on less oxygen than the constant flow systems.

Cylinders.

Steel Cylinders are usually tested every 10 years. Specially constructed composite oxygen cylinders could have a shorter period for hydrostatically testing. Most cylinders can be used indefinitely.

MASK OR CANNULA

Cannulas are light and comfortable, they deliver oxygen directly into the nostrils and allow normal use of the radio. Some on demand cannula systems claim to be able to cope with mouth breathing, but it is obviously desirable to nose breath!. The cannula type breathing devices can be used up to 18,000 feet. If a cannula is used, there should be a standby face mask available in case a head cold causes the user some nasal congestion

Masks have an expired air one way valve to allow air out and limit air in to that from the bag (keep it full) when fitted with a bag. They may or may not include a microphone for radio use. All should be a snug leak free fit on your face. Bags and valves obviously free from holes and blocking debris. Masks can be very inconvenient if the radio is busy as the straps usually fit under the sun hat. Hopefully you have a good radio, which can pick up your -shouted out of the bottom of the mask- communications.

FLOW INDICATORS

All systems should include some indicator that oxygen is flowing. It may be a simple in line indicator or a doll eye or a light that flashes but *you must monitor it. As you altitude increases the frequency of monitoring of the flow indicator must increase.*
The in line type of indicator is operated by the flow of oxygen. As soon as there is a flow of oxygen, the red indication is replaced with a green reading. The change from red to green only shows that there is a flow of oxygen. The green indication does not tell you that the system is working properly. As a matter of fact, the green indication on some of the red/green indicators will operate with a flow of oxygen required for less than 5,000 feet.
It will be obvious from the above that you need to be briefing on the particular oxygen system you will be using. However all systems will have many of the following characteristics in common.

Need to be turned on
Need to contain oxygen
Need to be leak free connections and fit
Need to be monitored for flow and contents
Need to be regulated
Must use dry *aviation* oxygen and not medical
Must not be emptied below 200psi to keep tank dry
Connection free of all but silicon as grease will explode
Some may need a dry cell battery- take a spare

HIGH ALTITUDE FLIGHT

VNE reduces due to reduction in aerodynamic damping
TAS increases
Temperature reduces moisture freezes batteries give less charge
Wind velocity changes sometimes markedly
Weather may close in before you can descend. You need to have practiced rapid descents.
Extra and unusual work load of oxygen system

SAFE OPERATION

1. Don't bend the rules, stay below 13,000 unless O2 available
2. Understand the weather system, don't leave your descent too late
3. Understand and monitor your O2 system flow and contents
4. Reduce VNE by 10%
5. Mentally monitor your performance, calculate ETA's & winds
6. IMSAFE ears; medications; asthma; hydration; fatigue; stress
7. Check your system on the ground and before you need it in the climb
8. The higher you go the worse are the consequences of O2 failure of canopy cracking or bailout.
9. Have preset decisions regarding flight and don't exceed them.
10. Hypoxia is insidious the first symptoms my be a feeling of well being, refer back to 9.