Oxygen and Altitude for Glider Pilots

Re written from Sailplane and Gliding June/July 1986
Dr Murray Wilson consultant anaesthetists in the Sheffield Children's Hospital and Plastic Surgery unit and has a qualification in aviation medicine. He took up gliding in 1980.

Overheard in the clubhouse "How much oxygen does a person need to survive?" "About 250 millilitres or a quarter of a litre each minute, of which the brain takes 20%". "Then why do I have to have such a high flow in the glider? If there is still some Oxygen in the air I should be able to manage with much less than 2 litres a minute."

Unfortunately, glider and hang glider pilots do not have a good reputation with regard to the use of oxygen. Recent criticism was levelled in the British Medical Journal at a hang glider pilot who had taken small puffs of oxygen from a tube in his mouth while attempting a high altitude cross-country flight. It is a sad reflection that the BGA had to introduce the recommendation that no Gold height could be accepted unless oxygen had been used.

Why are risks taken? Probably the two reasons are enthusiasm and ignorance. Along with ignorance goes the inability to recognise the onset of the effects of lack of oxygen (hypoxia). Enthusiasm results on the one hand in stories of makeshift equipment and on the other of "pressuring on". I recently heard of the episode where an oxygen mask was left behind, but a replacement fabricated from a cut-down squash bottle. All very fine in times of war but not for a sporting pass time. Does this approach also apply to repair of the glider its self? The successful return to earth does not negate the ancient phrase "Lack of oxygen not only stops the engine, but also wrecks the machinery".

THE conversation in the clubhouse demonstrates one of the more confusing aspects of the use of oxygen. If there is enough volume of oxygen in the inspired air, why is it not necessarily sufficient to support life? The answer lies in understanding that the pressure of oxygen is just as important, perhaps more so than the quantity.

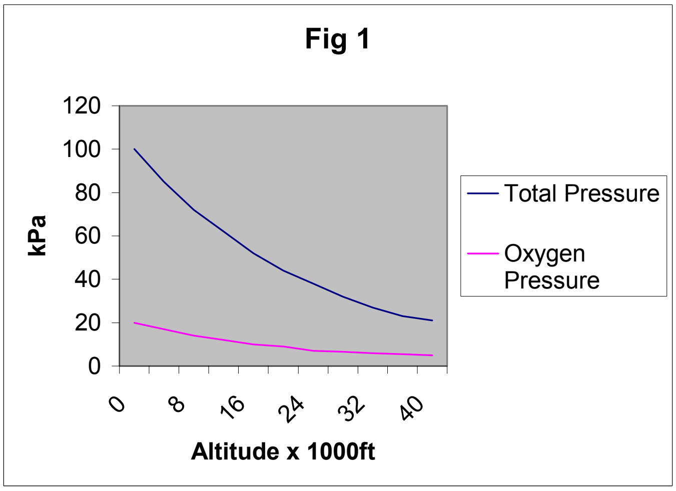
It does seem strange that despite the presence of apparently enough oxygen, if it is not at sufficient pressure it may not support life. This can be better explained by describing fizzy drinks which owe their fizz to dissolving carbon dioxide. Although the proportion of carbon dioxide is very low the average room contains about 1000 litres of carbon dioxide. Despite the enormous volume there is no way that this can be made into a fizzy drink unless pressure can force it into solution. A Sodastream injects only half a litre but does so at so high pressure. In the same way the oxygen we breath has to be at sufficient pressure to force it into solution in the blood.

The atmosphere. The pressure falls with increasing altitude, but the proportion of the gasses in the atmosphere constant, Table 1. THE fall is rapid at lower altitudes and

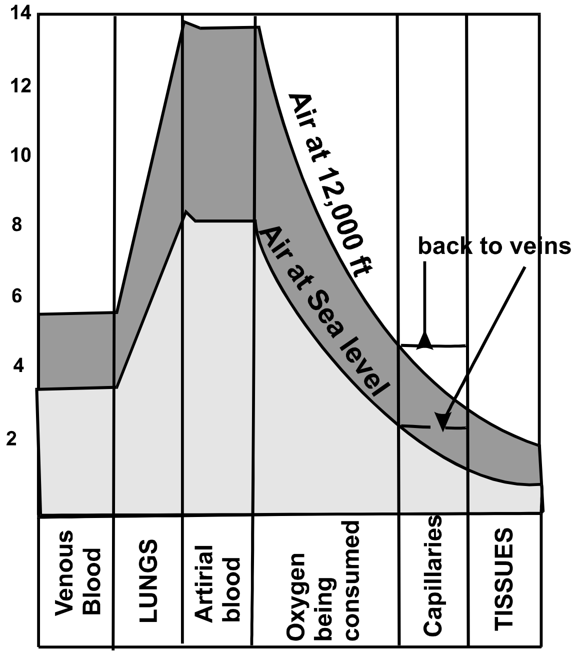
THE Atmosphere
Nitrogen……………….78%
Oxygen………………..20.9%
Carbon Dioxide ……….0.3%
Rare Gases……………0.9%

TABLE 1

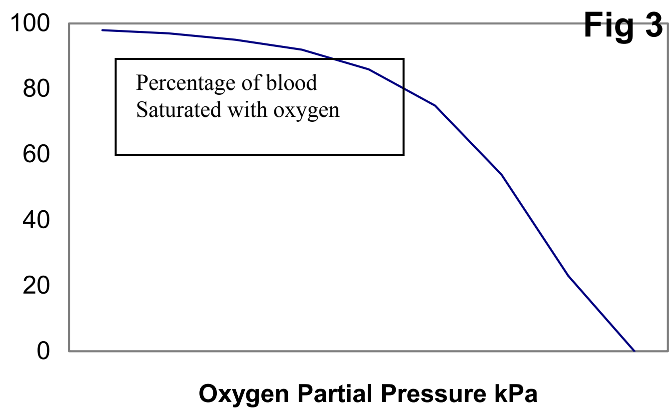
then slower (Fig, 1). Pressure at sea level is variously described as 1 Atmosphere, 1013.2mb, or approximately 100 kilopascals (kPa). Near sea level the pressure falls by one thousandth of an Atmosphere. Approx 1mb, for each 33ft. At 18500ft the pressure is one half an Atmosphere, (50kPa) and at 37,000 ft it is one quarter (25kPa). Each gas present exerts a pressure proportional to its concentration. As oxygen occupies at all times one fifth of the atmosphere, its partial pressure os one fifth of the atmosphere, its partial pressure is one fifth of the atmospheric pressure. Thus at sea level, oxygen pressure is one-fifth of an Atmosphere, or 20kPa. At 18500 ft this has fallen to 10kPa.



Inspired air id diluted in the lungs, and oxygen is taken out. Thus its pressure in the lungs is less about 14kPa, the normal at sea level. Oxygen is carried to the tissues where it is consumed, and so the lowest pressure is found here.



This progressive fall in oxygen pressure, known as the Oxygen cascade, is shown in Fig 2. Normal values are the solid line, from the left to the right the oxygen level is shown in the blood in the veins returning to the heart and lungs. In the lungs the oxygen pressure rises sharply to just that found in the arterial blood. The fall from the level in the lungs, to that in the arteries, is normally low but increases in any lung disease. As oxygen is given up the pressure falls to the venous level.



Diffusion caries oxygen into the tissues where it si consumed and the pressure falls further. It is the lowest that is actually sustaining life.

Nothing in the field is simple, and the amount of oxygen taken up by the red pigment, haemoglobin, of the blood has a complex relationship to pressure. Fig 3 shows the vertical axis the amount of oxygen taken up at the pressures shown on the lower horizontal axis. It can be seen that the amount absorbed does not much as the pressure is at first reduced from the normal 14kPa. Then from about 9 kPa downward the amount absorbed, and therefor the amount available to be used by the body, is markedly less. The values shown are for a normal person. If you have anaemia, even that produced by giving blood on the previous day, you are able to carry less oxygen, and will be more effected by altitude. Smoking, by converting the normal haemoglobin to an unreacting compound, reproduces the effect of anaemia. The haemoglobin takes days to be reconverted after a last cigarette.

Precipitous fall in absorbed oxygen will start at 12,000ft.

The upper horizontal axis of Fig 3 shows the altitudes equivalent to the pressures shown below. This demonstrates that the precipitous fall in absorbed oxygen will start at 12,000ft. The effect of breathing air at 12,000ft on the Oxygen cascade is shown on Fig 2, dotted line.

Volumes of breathing. While at rest we breath about 16 times a minute taking about 400 millilitres per breath. So we breathe at about 6.4 litres of which about 4 litres reach the lungs where gas exchange takes place. Thus we take in about four times as much oxygen as we need. This is typical of the “safety margin” that is found in the body. It is this safety margin that we start to erode at altitude. As the pressure falls, only a small increase in respiration is needed to maintain an adequate volume intake. This argument must not be taken as reducing the need for oxygen. The following example will demonstrate. At 37,000ft the total pressure is a quarter of the atmosphere, 25kPa. By over breathing to 12 litres a minute not at all difficult we could take in 600ml of oxygen, about twice the required amount. This sounds fine until it is remembered that an oxygen pressure of 5kPa will not support life, however hard we breathe. Additionally this extra breathing itself consumes oxygen.

Effects of hypoxia. The most important point about the effects of hypoxia is that they are insidious. Like the effects of alcohol they are less apparent to the sufferer than to an observer. Similarly the effects may not be unpleasant.

Up to 10,oooft a normal fit person will feel no effects. Passenger airliners are routinely pressurised to a cabin altitude pressure of around 6, 000ft. Research has shown that there is some impairment of the vision at as low as 5,000ft, and of complex mental activity at 8,000ft.

Above 10,000ft effects of which the subject is unaware progressively increase. The most obvious sign is an increase in respiration. As this can occur also because of anxiety, fright, cold or activity is by no means a specific sign. Above 15,000ft symptoms occur even at rest. Coordination is reduced, but as loss of critical judgement is also a feature, the subject is unable to judge how severe he is effected. Watch for light-headedness, tingling of fingers and toes, or around the mouth. Visual effects include haziness, loss of colour perception and general dimming. Headache may occur. Waiting for the nails to become blue (cyanosis) is to allow hypoxia to reach a very dangerous stage. Nearly all of the signs and symptoms described can be produced by over-breathing. If there is any doubt about the cause of any symptom always assume hypoxia is present. Check your oxygen system is running; use it if you are not already doing so; and **descend**. Forget the task, restore your oxygen pressure as soon as possible, and return to earth to investigate the cause.

Above 20.000ft symptoms occur quite rapidly and this may include sudden loss of consciousness. This unconsciousness may be followed by convulsions.

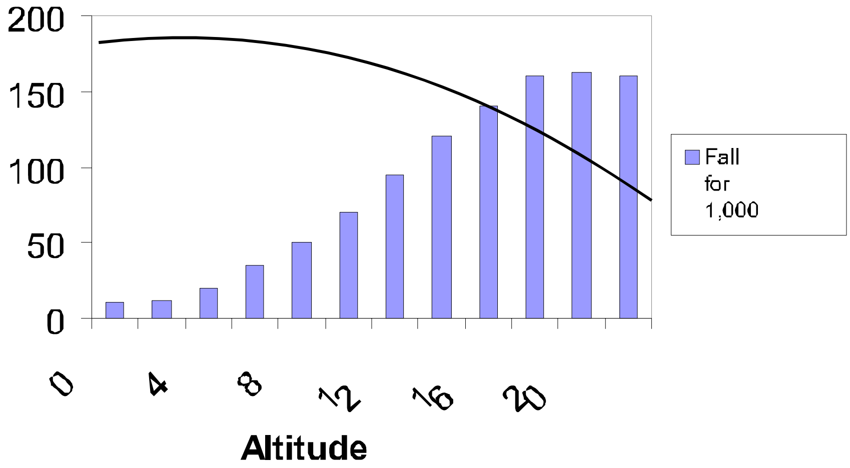
Variation from the normal. The foregoing refers to the effects expected in a normal person. Many factors influence individual tolerance but *all* of them reduce it. Reference has already been made to anaemia, including that produced by smoking. Any chest disease adversely influences the oxygen uptake. Physical activity increase the need for oxygen, as does cold which in itself clouds mental judgement. At 18,000ft the outside temperature is –20°C, and shivering can double oxygen consumption. All sedative drugs increase the effects of hypoxia. These include tranquillisers such as Valium. Antihistamines for hay fever and colds, and of course alcohol. Alcohol is a depressant drug and clouds judgement. A really heavy night at the bar can leave a significant alcohol level during the following morning.

The process of acclimatisation or becoming used to low oxygen levels takes weeks of months, and cannot be achieved even in a Silver duration flight.

Oxygen equipment. The function of oxygen equipment is to ensure that the inhaled oxygen equipment is to ensure that the inhaled oxygen pressure in the lungs nerve foes below that found when breathing at 10,000ft. Military equipment is precisely controlled and provides an accurate increasing concentration up to pure oxygen at 37,000ft, and increasing pressure above that. Glider equipment which must be cheap and light, aims only to ensure sufficient oxygen. Any error should be of over supply, the only disadvantage of this being a less-than-economic use of oxygen.

Oxygen is recommended at 10,000ft and mandatory at 12,000. Does pressing on “just another thousand feet” matter? The result is shown in Fig 4.

Fig



The vertical bars demonstrate the fall in content with each additional 1,000ft. As always there is no sudden at any altitude, merely continuous fall in available oxygen. The answer is the oxygen cascade where the devastating fall in oxygen at altitude can be seen, (dotted line in Fig2). To complete the story, it is important to watch the quantity of oxygen remaining in your cylinder as the human body only stores enough oxygen for about 4 minutes. Descending after exhaustion of the cylinder could not be sufficiently rapid to avoid the effects of hypoxia.