Hang Gliding Federation of Australia

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OXYGEN ENDORSEMENT MANUAL

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This manual lays out procedures for the use of oxygen for aircraft regulated under the Hang Gliding Federation of Australia.

This manual provides important information for using oxygen when flying above 10,000’ in aircraft that do not have pressurised cabins. As altitude increases, the effective amount of oxygen that we can utilise decreases.

All human beings must breathe oxygen to survive, and they begin to suffer adverse health effects when the oxygen level of their breathing air drops below 19.5 percent oxygen. Below 19.5 percent oxygen air is considered oxygen-deficient. At concentrations of 16 to 19.5 percent, people engaged in any form of exertion can rapidly become symptomatic as their tissues fail to obtain the oxygen necessary to function properly. Increased breathing rates, accelerated heartbeat, and impaired thinking or coordination occur more quickly in an oxygen-deficient environment. Even a momentary loss of coordination may be devastating to a pilot if it occurs while the pilot is performing a potentially dangerous activity. Concentrations of 12 to 16 percent oxygen cause tachypnea (increased breathing rates), tachycardia (accelerated heartbeat), and impaired attention, thinking, and coordination, even in people who are resting. At oxygen levels of 10 to 14 percent, faulty judgment, intermittent respiration, and exhaustion can be expected even with minimal exertion. Breathing air containing 6 to 10 percent oxygen results in nausea, vomiting, lethargic movements, and perhaps unconsciousness. Breathing air containing less than 6 percent oxygen produces convulsions, then apnea (cessation of breathing), followed by cardiac standstill. These symptoms occur immediately. Even if a pilot survives the hypoxic insult, organs may show evidence of hypoxic damage, which may be irreversible (Rom, W., Environmental and Occupational Medicine, 2nd ed.; Little, Brown; Boston, 1992).

You can't tell when you are being deprived of oxygen; therefore, oxygen should be used before it is needed. The most dangerous aspect of hypoxia is the insidious "sneaky" nature of its onset. Because the effects of hypoxia are primarily on the brain and nervous system, there is a gradual loss of mental faculties, impairment of judgment, coordination, and skill; but these changes are so slow that they are completely unnoticed by the individual who is being affected. Actually, a person suffering from mild or moderate hypoxia is apt to feel a sense of exhilaration or security and may be quite proud of his or her proficiency and performance although he or she may be on the verge of complete incompetence. Because hypoxia acts upon the brain and nervous system, its effects are very much like those of alcohol or of other drugs which produce a false sense of well-being. There is a complete loss of ability for self-criticism or self-analysis; some people believe that an individual can detect a need for oxygen by noting the increase in breathing rate, an accelerated heartbeat, and the slight bluish discoloration (cyanosis) of the fingernails. However, by the time these symptoms develop, the individual is more likely to be mentally incapable of recognizing these signs; he or she may decide that he or she has always wanted blue fingernails! Even while "spiraling" out of control, he or she may be convinced (if conscious at all) that he or she is doing this deliberately and enjoying it immensely.

At sea level the air we breathe is about 21% oxygen. The air we exhale is roughly about 4% to 5% more carbon dioxide and about the same amount less oxygen than we inhale. Ie the exhaled air contains about 14-16% oxygen.

The extraction of oxygen from the air we breathe and the exhalation of carbon dioxide works through a diffusion process. Ie because the oxygen in the blood in our lungs is at a lower concentration than the 21% from the air we breathe it transfers and replenishes the oxygen depleted blood. Similarly, the high carbon dioxide in the blood flows the other way- ie carbon dioxide is removed from the blood into our lungs and its expelled when we breathe out. So an important point is not only oxygen supply but carbon dioxide removal.[1]

How much oxygen do we use? The amount of oxygen in your blood can be measured using a pulse oximeter which measures the saturation levels of oxygen in your blood. This should be between 95% and 100%. Everyone has different oxygen requirements under different states of activity. If you are resting then the oxygen requirement is less that when you are exercising. Generally, we use somewhere from 200ml of oxygen per minute resting through to 4000ml of oxygen per minute when we are exercising.[2] Of course everyone is different and these are broad estimates.

As we get higher in altitude the effective amount of oxygen in the air decreases.[3] The important issue here is the partial pressure of oxygen in the atmosphere decreases making our lungs less effective in extracting the oxygen. The chart below shows the effective oxygen percent at different altitudes relative to that at sea level:

Altitude (feet)	Oxygen percent
0	20.9
5000	17.2
10,000	14.2
12,000	13.2
14,000	12.2
16,000	11.3
18,000	10.5
20,000	9.7

Reference: http://www.higherpeak.com/altitudechart.html

From the table above, even at relatively low altitude (eg 5000') we can expect our bodies to be oxygen deficient. [4] As mentioned previously the levels of oxygen that we require is different for each of us under different levels of physical and mental exertion. Essentially, we all manage the oxygen we breathe differently. However, as we get higher in altitude, if we are not in a pressured environment, such as a pressurized airplane, we will suffer oxygen deprivation. It has serious health effects.

[1] The whole respiratory system is quite complex. We are keeping it simple as explaining the whole system serves no useful purpose here. However, if we breathe in pure oxygen the balance of carbon dioxide being zero on the inhalation means the diffusion will cause a considerable lowering of carbon dioxide in our blood this causes hyperventilation as compared to hypoxia (which is too little oxygen).

[2] Reference: http://health-medi-issues.blogspot.com/2008/02/oxygen-requirements-of-exercise.html.

[3] The amount of oxygen in the air does not decrease with height, the amount of air does, so there is less air to breathe and that means less oxygen.

[4] The pressure of oxygen is 21% of 760 mm/Hg -> 160 mm/Hg, This is the partial oxygen pressure outside the body. Once inside the lungs this reduces to 102 mm/Hg because the lungs contain water vapour and carbon dioxide. This 102 mm/Hg is the minimum oxygen pressure a human needs to function normally. (http://www.experimentalaircraft.info/articles/human-factors-altitude.php)

The HGFA Operations manual (5.1.9) states:

No hang glider, paraglider or powered paraglider shall be flown at a height above 10,000 feet above mean sea level except where the pilot:

(a) Is not limited by controlled airspace;
(b) has an Oxygen Endorsement;
(c) is carrying and using an approved oxygen supply system, or
(d) is given written permission by CASA.

What is an "approved oxygen supply" system?

CAO95.8 states that an aircraft must not be flown at a height in excess of 10 000 feet above mean sea level unless each person in the aircraft is supplied with oxygen from a **supply system** approved by CASA or the HGFA (7.1(a)).

Whatever the HGFA approves it needs to stand up to scrutiny in the event of something going wrong. If the HGFA approve a supply system, CASA expect due diligence that what the HGFA has approved is defendable.

What could go wrong? A pilot is at 14,000ft and gets hypoxic because his HGFA approved oxygen system fails. In his irresponsible state of mind he then flies into the controlled airspace close by and causes an incident/accident with a passenger aircraft. At the coronial inquiry the question will be - was the supply system approved by HGFA appropriate and sufficient?

Whatever the HGFA puts forward needs to stand up to this test.

In CAO95.8 what do the words 'supply system' mean? As the pilot must fly with such a system to be within the requirements of CAO95.8. Supply system is not defined in CAO95.8.

There are a range of possibilities:

1. **A "supply system" can mean the physical equipment.**

For example, Wikipedia defines an **aircraft emergency oxygen systems** *as emergency equipment fitted to commercial aircraft, intended for use when the cabin pressurisation system has failed and the level of oxygen in the cabin atmosphere drops below a safe level. It consists of a number of individual oxygen masks stored in compartments above passenger seats, and some form of central oxygen generator.*

In this regard the 'supply system' is taken as the oxygen masks and the oxygen generator.

If the HGFA takes on board this definition then it needs to specify the physical properties of the equipment (for example face masks, cannula, bottled oxygen, chemical oxygen generator).

2. **A "supply system" can mean the minimum required level of oxygen that must be delivered.**

In many countries (Australia, USA, UK and Canada) there are rules regarding the minimum oxygen supply levels for many aircraft pilots. For example, in Australia CAO 108 states:

1.1 This section of Civil Aviation Orders contains specifications for aircraft oxygen ***systems*** *intended for operation at altitudes up to 40 000 feet and is applicable in such circumstances as may be specified by CASA or an authorised person under the Civil Aviation Regulations 1988.*

Further in CAO108 it is stated:

System arrangements: Portable oxygen units may be used to meet the crew or passenger breathing requirements.

Further CAO108 (6.1A) states that *flight crew members may use nasal cannula manufactured under the name "Oxymizer", subject to the following conditions:*
(a) the minimum flow of supplemental oxygen available for each flight crew member at various cabin pressure altitudes must not be less than 0.3 litre per minute at 10 000 feet altitude, increasing by 0.1 litre per minute for every 2 000 feet up to 18 000 feet altitude; (CAO108 6.1A).

There are various other 'systems' defined in CAO108 for flying at different altitudes.

The definition of 'system' in CAO108 specifies what the minimum level of oxygen is required as well as the type of delivery. However, emphasis is on the minimum level of oxygen that must be delivered.

In addition CAO108 (6.2) says that if demand equipment is installed for use then it must not be less than the flow required to maintain during inspiration, a mean tracheal oxygen partial pressure of 122mm Hg.

AO95.8 states that an aircraft must not be flown at a height in excess of 10 000 feet above mean sea level (amsl) unless each person in the aircraft is supplied with oxygen from a supply system approved by CASA or the HGFA (7.1(a)). Civil Aviation Order 108.26 provides system specifications for oxygen systems for air crew members and passengers at altitudes up to 40,000' amsl. Although CAO 108 should be applied across all altitudes the main operational requirement for paragliders and hang gliders is between 10,000' amsl and 18,000' amsl. There are two different types of oxygen delivery systems. One is a **continuous flow system**. This system provides a continuous flow of oxygen at a rate that is adjustable by the pilot from off to fully on. The applicable section is 6.1A of CAO108. This states that the minimum flow rate is 0.3litres per minute at 10,000' amsl increasing by 0.1litre per minute for every 2000 feet up to 18000' amsl. This results in the following minimum requirements:

Altitude (feet amsl)	10,000	11,000	12,000	13,000	14,000	15,000	16,000	17,000	18,000
Flow rate required (ml per min)	300	350	400	450	500	550	600	650	700
Flow rate required (litres per hour)	18	21	24	27	30	33	36	39	42

From the above table the minimum amount of oxygen required at 10,000' is 300ml per minute up to 700ml per min at 18,000 or 18 litres and 42 litres per hour respectively. Note the above figures are minimum requirements. Some products can supply up to 2ltrs of oxygen per minute. Too much oxygen can also cause problems but we are more interested in the minimum requirements. The minimum requirements are when using a portable system with a "Oxymizer" oxygen conserving cannula.[5]

The second type of oxygen delivery system is the **demand system**. This system detects when you begin to inhale and begins flowing. It adjusts the flow of oxygen for altitude differences. If a demand

[5] This nasal cannula is most likely the main system that will be used by hang gliders and paragliders. Most, but not all, oxygen delivery products can be used with this sort of cannula.
http://www.mhoxygen.com/attachments/132_Oxymizer.pdf

system is in operation then section 6.2 of CAO 108 is applicable. Section 6.2 requires that the minimum flow of oxygen required during inspiration, must maintain a mean tracheal oxygen partial pressure of 122mm Hg. This is approximately equivalent to an altitude of 5,000 feet amsl. In addition you must be able to turn on the demand system to obtain undiluted continuous flow oxygen.

3. A "supply system" can mean a specific product.

There are a range of manufacturers of oxygen supply products. These include Mountain High, Summit Oxygen and Oxy2go. The manufacturers supply a variety of portable oxygen supply products that deliver different amounts of oxygen through different equipment.

Conclusion

The HGFA has not approved any system. So one can only summize what might be the legal conclusion. In my opinion, an approved supply system is one where the minimum flow of oxygen must not be less than 0.3litres per minute at 10,000 feet, increasing by 0.1litres per minute for every 2000 feet up to 18,000 feet. An example of a product meeting this requirement is Mountain High EDS units distributed in Australia by Go Soaring: http://www.gosoaring.com.au/MountainHigh.php

EDS requirements

The oxygen requirement in CAO108 is 122mm of Mercury as the mean tracheal partial pressure of oxygen for a demand system (eg EDS).

What does this mean in terms of % oxygen saturation?

To work this out use the oxygen dissassociation curve. This converts mm of Mercury into partial pressures. At 122mm it equals 98.26% saturation.

OK so does the EDS meet the 122mm requirement?

Refer to the CAMI testing report. The results on page 18 show that subjects had a mean average partial pressure of 98.8% which is in excess of the standard equivalent of 122mm which is 98.26%.

Note than once you go above 18000 feet there is a different requirement and the HGFA doesn't have any requirements here so it's a bit unclear. I expect if there was a problem the HGFA would turn to the CAO 108 to establish what they consider approved.

Note also that the oxygen endorsement for HGFA members is only available for advanced rated pilots (HGFA Operations Manual 8.4.10).

Other issues to be aware of

Flying above 10,000 feet altitude comes with considerable additional safety issues other than reduced oxygen in the atmosphere. At higher altitudes temperatures are considerably colder, potential conflicts with other aircraft considerably more, turbulence associated with wind shear and stronger winds increased. To be able to adequately deal with the additional demands associated with oxygen use above 10,000 feet pilots need to hold a HGFA PG 4 or HG Intermediate rating for the aircraft that they are flying. There are also different altitude requirements for barometric altimeter settings relative to those below 10,000, different visual flight rules and issues regarding controlled airspace. These are discussed over the page and provide only a brief overview of these issues. More information can be obtained from CASA and/or the HGFA.

Altitude settings

Barometric altimeters are based on pressure of the air in the atmosphere. Generally, they have a main scale and a sub-scale. Setting the sub-scale to different pressures will alter the vertical position on the main scale. As you fly higher the pressure decreases and this can be recorded by the barometric altimeter as a change in the vertical position of the aircraft. As motorized or jet aircraft are flying at relatively high speed as they travel across the country they travel through areas of different pressure. This means that if they stayed at the same absolute vertical position their altimeter would record different heights as they moved through areas of different pressure. One way around this is to have areas where the pressure is known and the altimeter can be reset as they come into each area. The problem with this is that the pilot would be continuously adjusting the altimeter as they flew through different pressure areas. Given the variations that can be seen on synoptic charts this can become problematic. To resolve this problem a standard altimeter setting has been established. This standard setting is known as QNE. If everyone sets their altimeter to QNE then everyone knows where they are relative to each other. However, the QNE setting is only an approximation. Once you get down close to the ground it becomes more critical to have a more accurate measure. This requires a different sub-scale setting on the altimeter and is referred to as QNH. It is the altitude above means sea level based on the current location pressure. If you are close to an airfield then you may refer to your vertical position above the airfield. This is called QFE. Therefore, different phases of flight require different altimeter sub-scale settings. These are QNE (flight level), QNH (altitude), QFE (height).

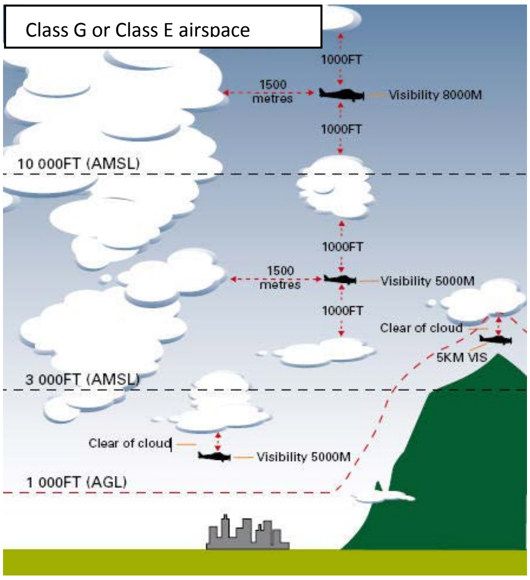
QNE: Once you get **above** 10,000' AMSL. Flights above this level are referred to flight levels (FL). The altimeter sub-scale is set to the standard pressure of 1013 hPa (hectoPascal/millibar). The aircraft's vertical position (in feet, divided by one hundred) is referred to as a flight level instead of an altitude. For example 15,000 feet is FL150. Therefore, for all aircraft above 10,000' amsl their vertical position is referred to as their flight level. This is suitable because terrain is not a problem and it resolves the issues about different pressures.

QNH: Flight levels **below** 10,000' AMSL are referred to as altitudes where the altitude is set to a regional or airfield pressure (QNH). This is an altitude above mean sea level (AMSL). QNH is the mean sea level pressure which is derived by reducing the measured pressure at ground level to mean sea level using the specifications of the International Civil Aviation Organisation (ICAO) standard atmosphere. An aircraft's altimeter, when set to an airfield's QNH, will give the aircraft's approximate elevation (vertical distance above mean sea level of a point on the earth's surface) when the aircraft is on the airfield; and will give the aircraft's approximate altitude (vertical distance AMSL) when the aircraft is above the airfield. When the aircraft moves away from the airfield (or out of the barometric area) then the altimeter needs to be reset to provide the correct altitude on QNH or if above 10,000' AMSL it is set to 1013hPa.

QFE: QFE refers to the altimeter setting that will cause the altimeter to read the aircraft height above a specific aerodrome or ground level, and therefore read zero on landing at that location. While using QFE is convenient while flying in the traffic circuit of an airfield. When the altimeter is set to QFE the aircraft position is referred to as height.

Visual Flight Rules

In addition to different barometric altimeter settings, there are issues regarding visual flight rules (VFR) that differ above 10,000’ from those below 10,000’ AMSL. In all cases the horizontal distance from cloud is 1500meters and 1000 feet vertical separation regardless of altitude or flight level. However, if above 10,000’ AMSL the visibility requirement is extended from 5,000 meters to 8,000 meters. This is shown below. Note paragliders and hang gliders cannot fly above cloud. Information regarding VFR is obtainable from the HGFA Operations Manual



Airspace

Generally, paragliders and hang gliders fly in Class G airspace. If a paraglider or hang glider pilot wishes to fly in Class E airspace they are required to carry and use a VHF radio if required. The terminology used here is that the pilot must maintain a ‘listening watch’ on the appropriate frequency. Class D airspace requires ATC approval to enter. Paragliders and hang gliders cannot fly in any other airspace. In addition, generally within 10nm of a registered or certified aerodrome a VHF radio must be carried and used. In areas where there is no radar coverage Class G airspace generally goes to FL180 or FL245 before controlled airspace begins. In other areas Class E airspace may begin at 8,500 feet AMSL or FL125 and other controlled airspace begins at FL180. You must be aware of the different requirements in Class G and Class E airspace. Information regarding airspace is obtainable from VTC and ERC charts.

Conclusion

Flying above 10,000 feet AMSL requires additional skills that are more demanding and sometimes very different to flying below 10,000 feet. These additional skills are generally embodied in the various rules and regulations that are established to make the sport of paragliding and hang gliding safer and more enjoyable. These rules relate to oxygen use, altimeter settings and flight levels, visual flight rules, airspace and VHF radio use. Please ensure you are fully informed of all the requirements.

Have a safe flight.

OXYGEN ENDORSEMENT THEORY STUDY GUIDE

1. **What is the purpose of oxygen in the air we breathe?**
2. **Where is the main standard for oxygen requirements for members of the HGFA?**
3. **At what percentage level of oxygen below which we can experience adverse health effects of oxygen deprivation?**
4. **At what percentage level of oxygen below which we can experience impaired thinking?**
5. **At 10,000 feet altitude amsl what is the effective percentage of oxygen in the air?**
6. **At 10,000 feet altitude amsl what are some of the likely adverse health effects of lack of oxygen?**
7. **What is the approximate percent oxygen in the air at sea level?**
8. **How do you measure the amount of oxygen in your blood?**
9. **What level of oxygen saturation should be in your blood if you are absorbing sufficient amounts?**
10. **What is the altitude above which you must carry and use oxygen?**
11. **Between 10,000-18,000 feet altitude amsl what are the type of oxygen system that can be used by hang glider and paraglider pilots?**
12. **What flow rates are specified as flow rates for oxygen use using an 'Oxymizer' cannula?**
13. **What flow rates are specified as minimum flow rates for oxygen use at 5,000' and 10,000' altitude amsl for continuous flow?**
14. **For altitudes between 10,000 feet and 18,000 feet amsl what are the oxygen flow requirements for continuous flow?**
15. **If a demand oxygen system is in use what is the mean tracheal oxygen pressure that must be maintained?**
16. **What is the license rating required to obtain oxygen endorsement?**
17. **If flying above 10,000 feet altitude amsl what barometric altimeter sub-scale setting is used?**
18. **What is the VFR for flying above 10,000 feet altitude amsl?**
19. **What is required for a paraglider or hang glider to fly in Class E airspace below 10,000 feet amsl?**
20. **What is required for a paraglider or hang glider to fly in Class E airspace above 10,000 feet amsl?**