LOOKING THROUGH THE OXYGEN WINDOW.

By Bruce R. Wienke, NAUI 5343, and Tim R. O'Leary, NAUI 10144

Seems there is much talk by the tech diving community about the oxygen window (à la Behnke) or inherent un-saturation (à la Hills) or partial pressure vacuum (à la Sass). All terms describe the same thing–the under saturation of a diver's tissue and blood with respect to ambient pressure. This window is necessary to facilitate the transfer of fresh oxygen, needed for metabolism, and the elimination of carbon dioxide, a waste product of metabolism, efficiently. The pulmonary (lungs) and circulatory (arteries and veins) systems form a closed gas transfer network to in gas oxygen and outgas carbon dioxide consistent with workload requirements of the human body.

Both oxygen and carbon dioxide are active (metabolic) components, while nitrogen, helium, neon, argon, water vapor, etc are inactive (inert) players in processes The possible impact of inert gases on metabolic processes is not fully known, especially as levels of inert gases rise in tissues and blood, but to the lowest order for diving, oxygen and carbon dioxide are primary components in metabolic sensing and control, and the rest are passive.

For divers, the window is an important factor in staging because it impacts both inert and metabolic gas uptake and elimination. We'll return to this, but let's first start at the beginning.

Tissues and venous blood are typically under saturated with respect to inspired air and arterial tensions by somewhere in the vicinity of 8-13% of ambient pressure at sea level. Figure 1 depicts the under saturation at sea-level atmospheric pressure, nominally 33 fsw, neglecting atmospheric trace gases. Note that arterial, venous, and tissue total tensions are all less than 33 fsw by about 0.7 fsw, 2.9 fsw, and 3.7 fsw respectively, while nitrogen and water vapor partial pressures are the same across lung, arterial, venous, and tissue domains–24.7 fsw and 2.0 fsw. Tissue and venous blood tensions also fall below arterial tensions. Lung gas partial pressures are close to arterial tensions. Also note that arterial oxygen tensions are more than double venous oxygen tensions and more than five times tissue oxygen tensions. Tissue carbon dioxide tensions exceed both arterial and venous carbon dioxide tensions by a small amount (just enough). Gradients for oxygen transfer are large and inward, while gradients for carbon dioxide are small and outward. This gas transfer network sustains life–obviously.

How is such a pressure head maintained for in gassing oxygen and out gassing carbon dioxide? Simply, carbon dioxide produced by metabolic processes is 25 times more soluble than oxygen consumed, and hence by Henry's law, carbon dioxide exerts a lower partial pressure. Such an arrangement of tensions in the tissues and circulatory network provides the pressure head between alveolar capillaries of the lungs and systemic capillaries in extra cellular body space. And the lower solubility of oxygen versus carbon dioxide maintains it.

What happens if helium replaces nitrogen in the above depiction? Nothing really changes for any inert gas replacing nitrogen in the breathing mixture, nor for combinations of nitrogen and helium, provided the mole fraction (total) of inert gases and the ambient pressure is the same. To lowest order in Figure 1, the same relationships obtain for a breathing mixture of 21% oxygen, with the remaining 79% being inert gases of any brand. It's the mole fraction of oxygen and ambient pressure that are keynote.

What happens if ambient pressure changes, or mole fraction of oxygen changes? That's a different story, of course. Changes in ambient pressure and/or oxygen mole fraction affect the inherent un-saturation for oxygen partial pressures (ppO2) below two atmospheres, roughly.

Ranging experiments suggest:

— the degree of un-saturation increases linearly with ambient pressure for constant composition breathing gas; and

— the degree of un-saturation decreases linearly with mole fraction (total) of inert gas in the inspired mix.

Beyond oxygen partial pressures of two atmospheres, the inherent un saturation is pretty much constant, somewhere in the 70 fsw (2.12 atmospheres) range. In all above, if the mole fraction of oxygen is fixed, then so is the mole fraction of inert gases–and vice versa, of course.

So how does this affect diving? Under compression-decompression, the active gases (oxygen, carbon dioxide, water vapor) are thought to be replaced with inert gases until the window establishes itself at some new ambient pressure. Subtracting the oxygen window from the inspired oxygen gives the magnitude of the additional inert gas loading, a loading added to the tissue tensions across all compartments. Equilibration time scales for reloading the window at some ambient pressure are thought to be on tissue halftime scales. This active gas contribution to tissue tensions from the window is roughly 5 fsw for inspired oxygen partial pressures up to two atmospheres, and it increases beyond that linearly as inspired oxygen partial pressures increase. Mmost tech diving maintains oxygen partial pressures well below two atmospheres, so the additional loading is constant. Hope so.

Years ago, Behnke advocated staging divers so that the oxygen window took up inert gas loadings. By staging the ascent strategically, using the inherent un-saturation to take up the inert gas super-saturation, the total tissue tension could be kept equal to ambient pressure. This approach to staging is called the zero super-saturation ascent. It works, is very safe, particularly for saturation diving, but takes a very long time compared to limited super-saturation ascents which are employed in dissolved gas and bubble algorithms.

Sources Naui-Tec

www.nauitec.com