The Diving Medical Advisory Committee

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Oxygen Content in Open Circuit Bail-out Bottles for Heliox Saturation Diving

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Supersedes DMAC 04 Rev. 1, which is now withdrawn

Background

The optimal oxygen content for secondary (bail-out) breathing systems depends upon a balance between the risks associated with the adverse effects of a high oxygen level and the potential positive benefits of a high partial pressure of oxygen (pO_2). In this guidance we present recommendations for the oxygen contents in bail-out bottles for heliox saturation diving with the objective of keeping the risk of acute toxic effects of oxygen at an acceptable level.

The advice below is based on physiological calculations and some underlying assumptions derived from the literature presented in a report by Segadal[1], discussions during a DMAC workshop in October 2014 and some other sources of information including current diving manuals.

Oxygen in a Bail-out Situation

There are some potential benefits in having a high pO_2 in the emergency gas reserve. One is potentially prolonged survival due to the higher oxygen saturation of tissues after the bail-out reserve has been emptied. Another is the impact of increased pO_2 (and corresponding reduced partial pressure of inert gas) on the risk of decompression sickness. The former can be considered marginal as the additional amount of dissolved oxygen available for metabolism after ventilation has ceased is small compared to the oxygen consumption of the body. The latter would be relevant if the diver, during or after the bail-out situation, experiences pressure changes that may induce decompression sickness. In most saturation diving situations excursion distances are small and the likelihood of a substantial pressure change is very small.

The acute toxic effects of high oxygen pO_2 may occur during the relatively short term exposure in a bail-out situation and the occurrence of seizures or loss of consciousness may have serious consequences in a bail-out situation. Longer term adverse effects of high pO_2 are considered irrelevant in this situation.

A number of factors are known to or suspected to influence the development of acute oxygen toxicity. Immersion, increased workload and elevated pCO_2 will enhance acute oxygen toxicity. It has also been suggested that there is a potentiating effect of inert gas partial pressure and gas density. Experimental work shows a large inter and intra individual variability in susceptibility of oxygen induced convulsions.

It is our opinion that when calculating the pO_2 in the bail-out cylinders, the risk of an oxygen induced convulsion should be minimal since nothing should interfere with the diver's ability to return to the safety of the bell.

The literature review by Segadal identified the equation presented by Morrison and Reimers[2] as the best available published physiological calculation, and calculated a series of maximal pO_2 levels for different depths based on this equation. However, the author noted that the basis of the equation is weak, that various factors are not included and suggested implementation of a 'precautionary approach'.

1 Segadal, K. *Bailout bottle – pO_2 limits*. Bergen: Norwegian Underwater Intervention A/S, 2015.03.12. Report No.: NUI 2014-19

2 Morrison JB, Reimers D. *Design principles of underwater breathing apparatus*. In: Bennett PB, Elliott DH, eds. *The Physiology and Medicine of Diving*. London: Bailliére Tindall, 1982: 55-98

Advice

It was the committee's view that a precautionary approach was appropriate since the impact of an oxygen convulsion occurring during a bail-out situation might prove fatal. The committee noted that the data forming the basis of the Morrison and Reimers equation was not directly related to the saturation diving situation and that clinical experience in the years since the equation was published suggest that oxygen convulsions may occur at a lower level of pO_2 than previously recognised.

The committee recommends that the **maximum** pO_2 supplied to the diver from the bail-out bottle should be 1.4 bar. The guidance recognises that the bail-out situation may involve periods of intense exertion but might also involve much longer periods of low physical strain. The recommended limitation is somewhat more conservative than calculated limits based on the Morrison and Reimers equation.

The committee recommends that the **minimum** pO_2 supplied to the diver from the bail-out bottle should be the same as the pO_2 in the diver's primary breathing gas mixture, with an absolute minimum of 0.4 bar.