PDIS: PROFILE-DEPENDENT INTERMEDIATE STOP

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Background

In recent times, deep stops have become quite popular amongst divers of all levels. The conventional deep stop is carried out at half of the max depth for no stop dives, and at half the distance between the max depth and the depth of the first decompression stop for decompression dives. It has been argued whether such stops are beneficial and, if so, under what circumstances.[1), 2)] We propose an optimized “intermediate” depth for a stop, which accounts for the details of the dive profile itself, for repetitive dives and for nitrox.

Materials and Methods

PDIS is embedded in the Bühlmann-based UWATEC ZH-L8 ADT, with half times between 5 and 640 minutes. The calculated depth for the intermediate stop is that at which the 20-minute compartment (40-minute compartment in presence of significant remaining saturation from a previous dive) in the decompression calculation switches from ongassing to offgassing. This ensures that, within the underlying Haldanian logic, at the prescribed depth at least three compartments are offgassing, of which two (5 and 10 minute half times) under a relatively high pressure gradient. Furthermore, the depth of the stop is a consequence of the dive profile itself and not tied solely to the maximum depth reached. Because PDIS accounts for the actual nitrogen uptake in the body, it is repetitive-dive dependent and also nitrox dependent. In the following we examine the PDIS analytically for square dive profiles and then also by means of the PC software SmartTRAK for simulated and actual recreational dives.

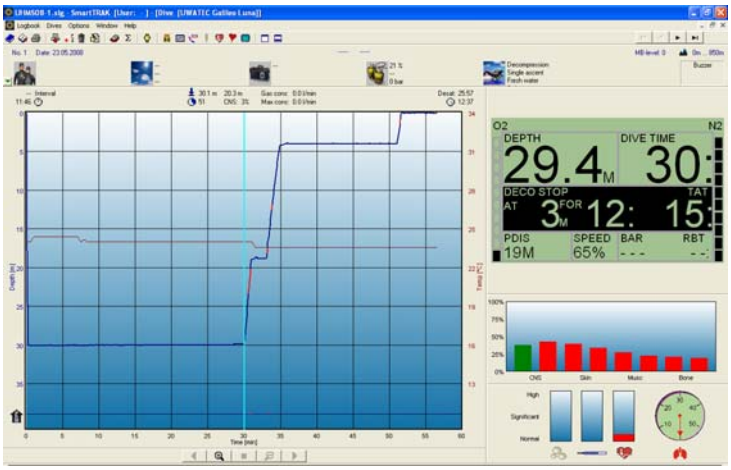
Discussion

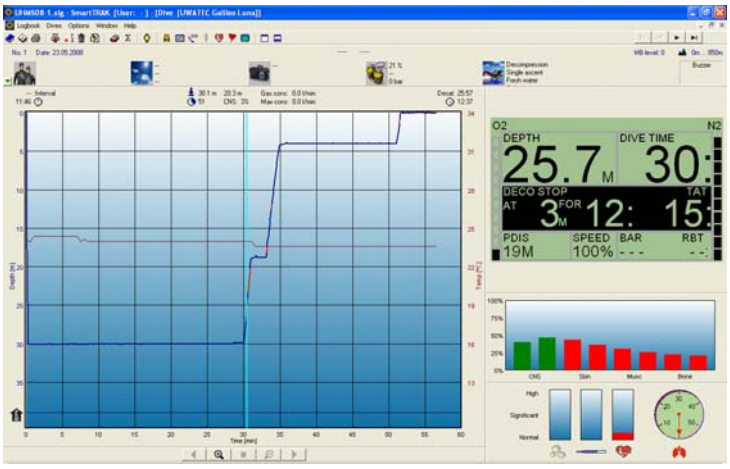
The analytical expression of PDIS as a function of time for a square non-repetitive dive for a generic compartment of half time τ can be obtained by assuming tissue saturation to 0.8bar prior to the dive, then following the tissue saturation by diffusion, and eventually equating this to the ambient nitrogen partial pressure at an unknown depth D_{PDIS} . The resulting equation is shown below, and in the table next to it we list the computed PDIS depth for maximum depths of 30 and 40m, using air and EAN32, for bottom times of 10, 20 and 40 minutes respectively, and tissue half time of 20 minutes.

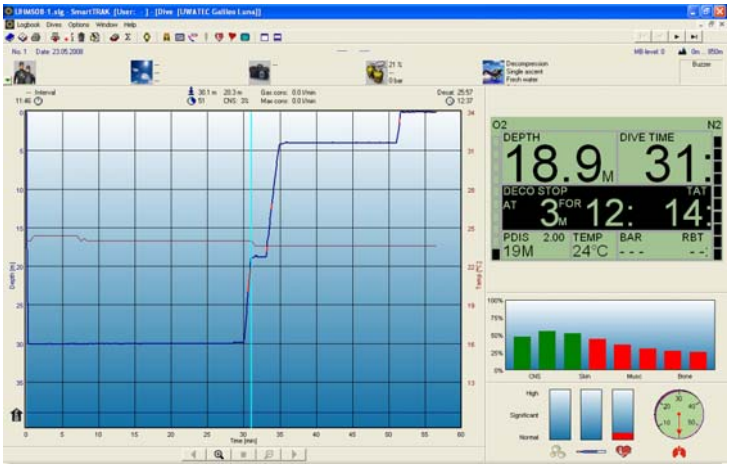
$$D_{PDIS} = D - 2^{-\frac{t}{\tau}} \times \left(D + 10 - \frac{8}{F_{N_2}} \right)$$

τ = 20 minutes	t = 10 minutes	t = 20 minutes	t = 40 minutes
30m air	8.8m	15m	22.5m
30m EAN32	10m	15.9m	22.9m
40m air	11.8m	20m	30m
40m EAN32	13m	20.9m	30.4m

The concept behind PDIS is to define a depth for an intermediate stop such that, within the haldanian framework of the decompression model, during the stop itself there is a tangible effect for the diver. By choosing the depth at which the 20-minute compartment is offgassing, we ensure that during the stop the fast 5 and 10 minute compartments, modelling the sensitive CNS tissues, are allowed to release nitrogen under a relatively high pressure gradient while at relatively high ambient pressure. In the following pictures we illustrate this by means of screenshots from the PC software SmartTRAK for a square dive to 30m. These show the dive profile (to the left), the dive computer display (top right) and a graphic representation of the behaviour of the 8 compartments in the ZH-L8 ADT algorithm (middle right). The height of each bar represents the saturation relative to the maximum tolerated saturation by that tissue at that ambient pressure. The color represents whether the tissue is ONGASSING (red) or OFFGASSING (green). The three following pictures show the situation at various stages during the final ascent.

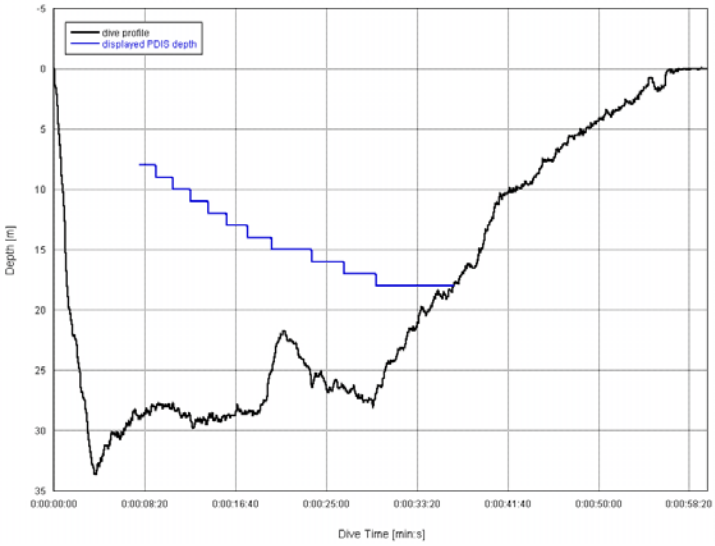


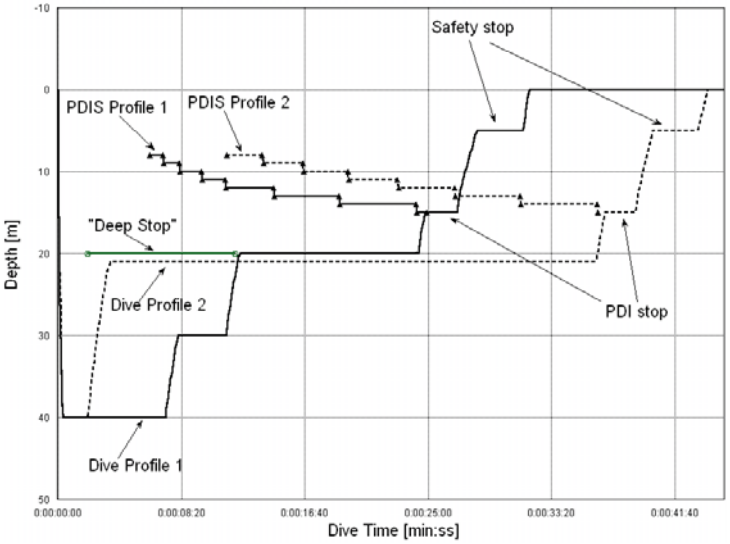




In particular, the three screenshots are selected to show at which depth the 5-minute, 10-minute and 20-minute compartmens switch from ongassing to offgassing. We see that this happens at 29.4, 25.7 and 19m respectively. From this we realize that while at an ambient pressure of 2.9bar (19m), the 5-minute compartment is offgassing under a pressure gradient of 1.04bar (29.4m-19m), while the 10-minute compartment is offgassing under a pressure gradient of 0.67bar (25.7m-19m). While the diver is performing the two minute stop, these tissues are able to release nitrogen while minimizing the possibility of microbubble growth, which is the purpose of the intermediate stop.

To the right we see the application of the PDIS concept to an actual recreational dive, in which EAN34 was used. Starting at 8 minutes into the dive, the diver sees a slowly increasing value of the PDIS, as the tissues increase their nitrogen partial pressure, until the diver eventually reaches the depth at which the 20-minute compartment is offgassing and performs the PDI stop (18m).





To the left we see a comparison between two no-stop dives to a maximum depth of 40m but otherwise very different. Consequently the PDIS evolution is also very different. The conventional deep stop, however, would be constant at 20m for both profiles.

Conclusions

PDIS offers an interpretation of the deep stop concept which does not conflict with the underlying Haldanian logic of the decompression model. The same cannot be said of “conventional” deep stops. Thus PDIS represents the preferred solution until full bubble models such as Copernicus [3] become commercially available.

References

1) A. Marroni, P. B. Bennett, F. J. Cronje, R. Cali-Corleo, P. Germonpre, M. Pieri, C. Bonuccelli, and C. Balestra, "A Deep Stop During Decompression from 82 Fsw (25 M) Significantly Reduces Bubbles and Fast Tissue Gas Tensions," *Undersea Hyperb Med,* vol. 31, pp. 233-43, 2004.

2) J. E. Blatteau, M. Hugon, B. Gardette, J. M. Sainty, and F. M. Galland, "Bubble Incidence After Staged Decompression from 50 or 60 Msw: Effect of Adding Deep Stops," *Aviat Space Environ Med,* vol. 76, pp. 490-2, 2005.

3) C.R. Gutvik, A. Møllerløkken, A. O. Brubakk, ”Copernicus and the deep stop”, Deep stop workshop, Undersea and Hyperbaric Medical Society Annual Meeting, Salt Lake City, 24-25 June 2008.