Correction for adiabatic effects in the calculated instantaneous gas consumption of scuba dives

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Introduction

Instantaneous gas consumption is generally calculated from the fall in cylinder pressure without considering the effects of water temperature (heat transfer) and adiabatic processes.
Aim:
1. Develop a simple but precise method for calculating the instantaneous air (or gas) consumption, AC, corrected for adiabatic-, heat transfer-, changing water temperature-, pressurizing lung- and BCD-effects).
2. Apply this to simulations and real dives.

Methods

Model With gas thermodynamics and water-gas heat transfer, the instantaneous released gas mass was modelled with known depth, cylinder pressure and water temperature (recorded with a Galileo dive computer).
Five subjects made an open-water, air-scuba dive to 32 metres sea water.

Application Seven divers made a deep low-effort recreational air-scuba dive to 34 msw (ascent pace 20 msw/min).

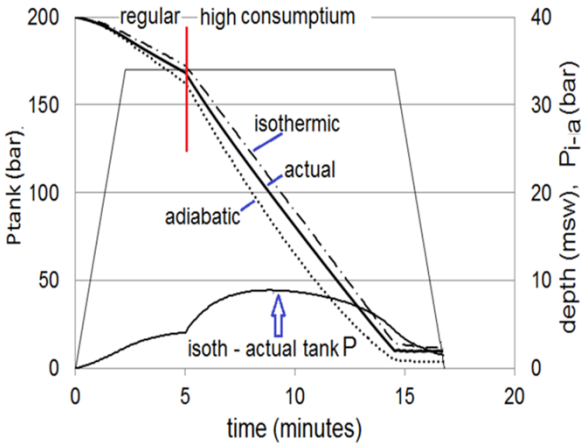

Fig. 1 Simulation to 34 msw. Regular AC is 17 aL/min and high is 43 aL/min. The 3 upper curves give the tank pressure for the 3 conditions. The lower one the adiabatic effect on tank pressure (the "extra" air).

Results:

Model The model-calculated air mass in the cylinder was the same as measured from cylinder data of the dives → model is adequate.
Model shows that adiabatic effects can result in considerable overestimates, depending on profile, exercise (Fig. 1), cylinder volume, water temperature.
Adiabatic phenomena are substantially different between square and saw-tooth profiles.
In the emergency situation of a nearly empty cylinder after a square-wave dive involving heavy physical exertion, the adiabatic effect provides some extra air during a well controlled ascent with sparingly ventilation (Fig. 2).

Application The descent of a dive with a uniform exercise level demands ca. 60% more gas than the "iso"pressure phase.

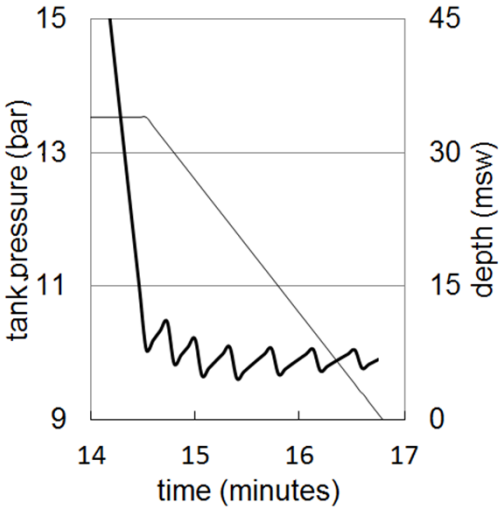

Fig. 2 Tank pressure during ascent from the 34 msw when the first stage blocking pressure (10 bar) is reached and the emergency ascent starts.

Conclusion

Adiabatic effects can be substantial.
The developed method seems sufficiently accurate for research and is implementable in dive computers.

For maths and details see Schellart & Le Péchon, DHM 2015;45(4):221-7.