De Diepe Stop; Zin en Onzin

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Theorie

Risico op DCZ hangt sterk samen met VGE.

Van belang: opgeloste N_2 en N_2 in gasfase (bellen):

1. Alleen opgelost: **Haldane model**.

2. Opgelost en als bellen: **Twee-fase model**.

Beiden zijn strijdig inzake opstijging, i.h.b. keuze diepte 1ste stop, namelijk ..

Haldanian Model:

go as shallow as possible (maximize ascent gradient), such that DCS risk is just acceptable.

Dual Phase Model (e.g VPM or RGBM):

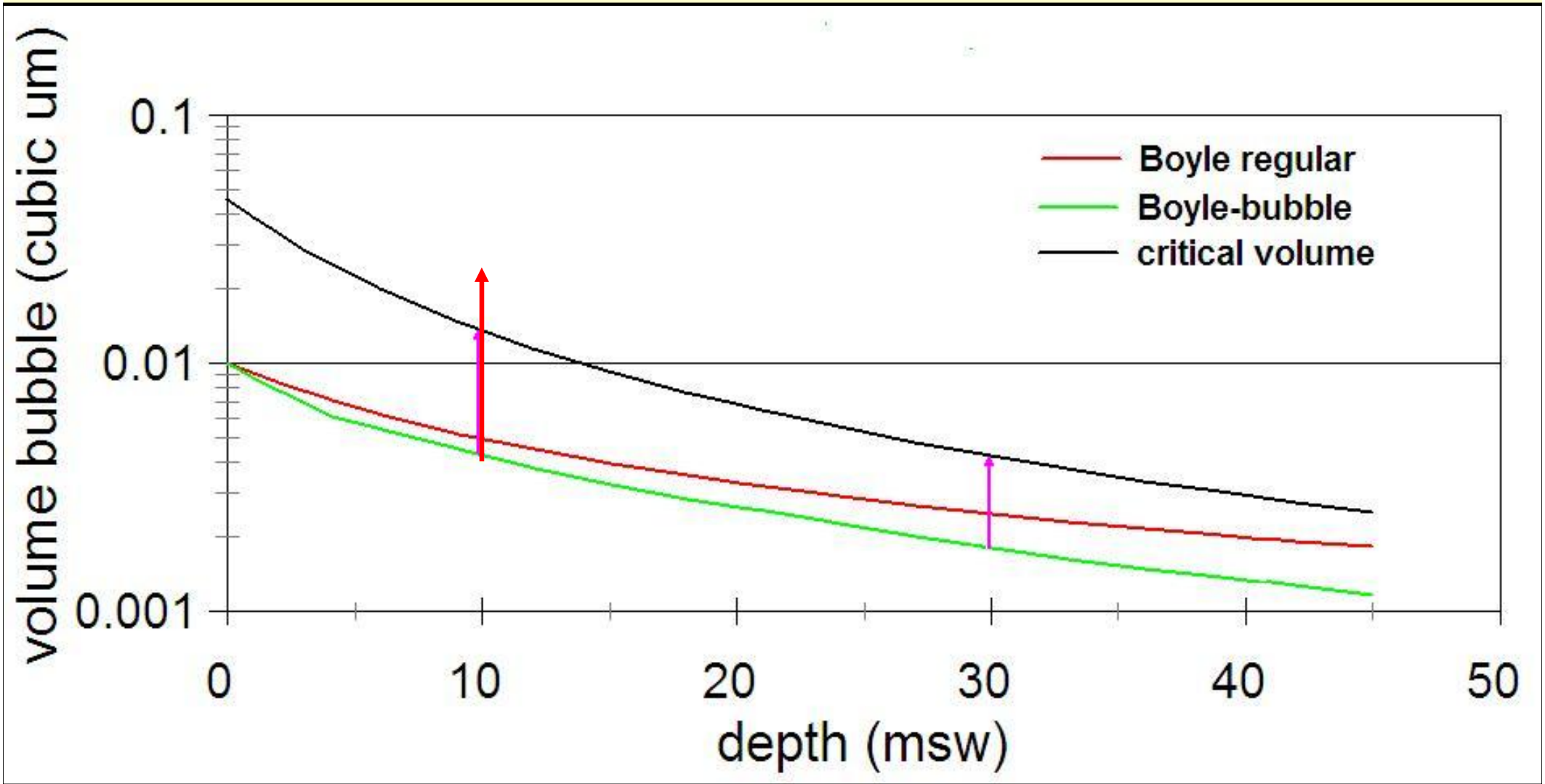
not shallow stop, but reduce ascent gradient, i.e. make deep stop (ca. 0.5 MDD) to prevent bubble grow.

How behave bubbles during ascent?

Bellen hebben kritische groottes (v_{crit}). Er boven: autonome **groei**, er onder autonome **krimp**.

v_{crit} neemt (gelukkig) zeer snel toe met afname diepte.

Maar ….



Haldanian Model:

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Dual Phase Model (e.g VPM or RGBM):

not shallow stop, but reduce ascent gradient, i.e. make deep stop (ca. 0.5 MDD).

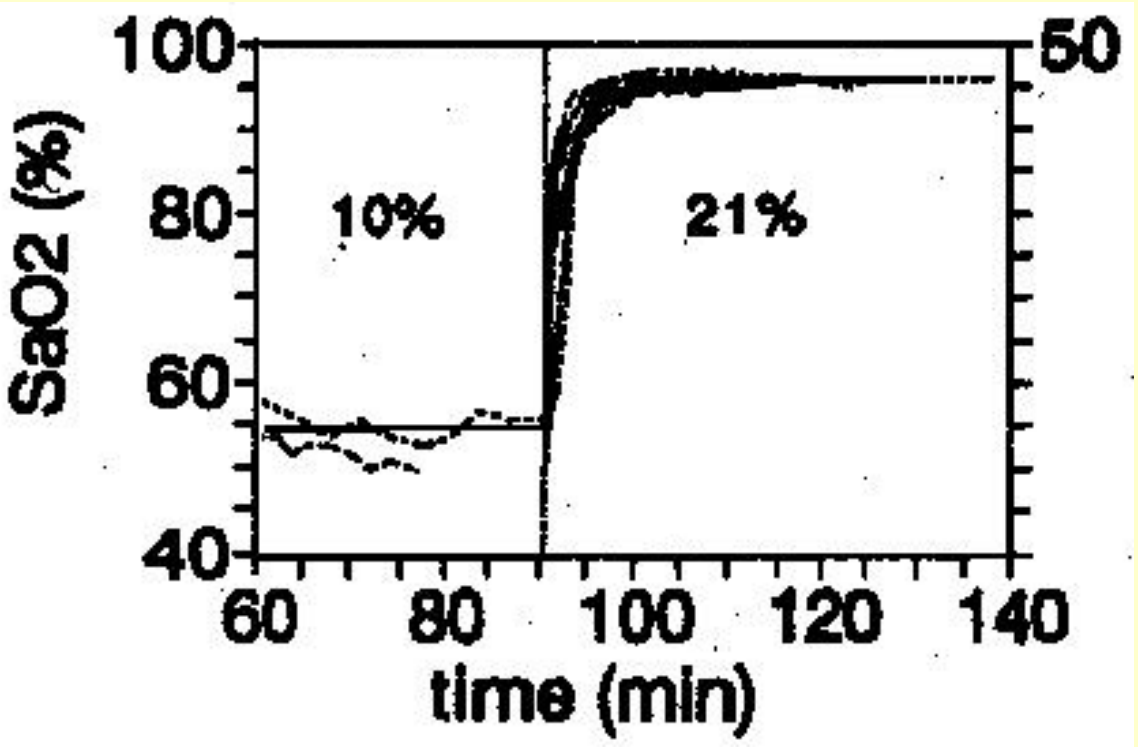
When bubbles off-gas a little at depth:

- Then bubble will **not grow** by transport of supersaturated tissue (blood) to bubble.
- Also prevents that new **surfactant molecules** are incorporated in bubble skin.

Hoe snel gaat uitwassen (N_2 opgelost + gas) in bloed?

Wat is "**halveringstijd**" bloed?

(Bloed heeft pseudo-halveringstijd, want long wast intermitterend uit!)



Schellart NA, Reits D. Transient and maintained changes of the spontaneous occipital EEG during acute systemic hypoxia. Aviat Space Environ Med. 2001;72:462-70.

Methode 1

halveringstijd SaO_2 2 min.

halveringstijd pO2 < 2 min (1,5?).

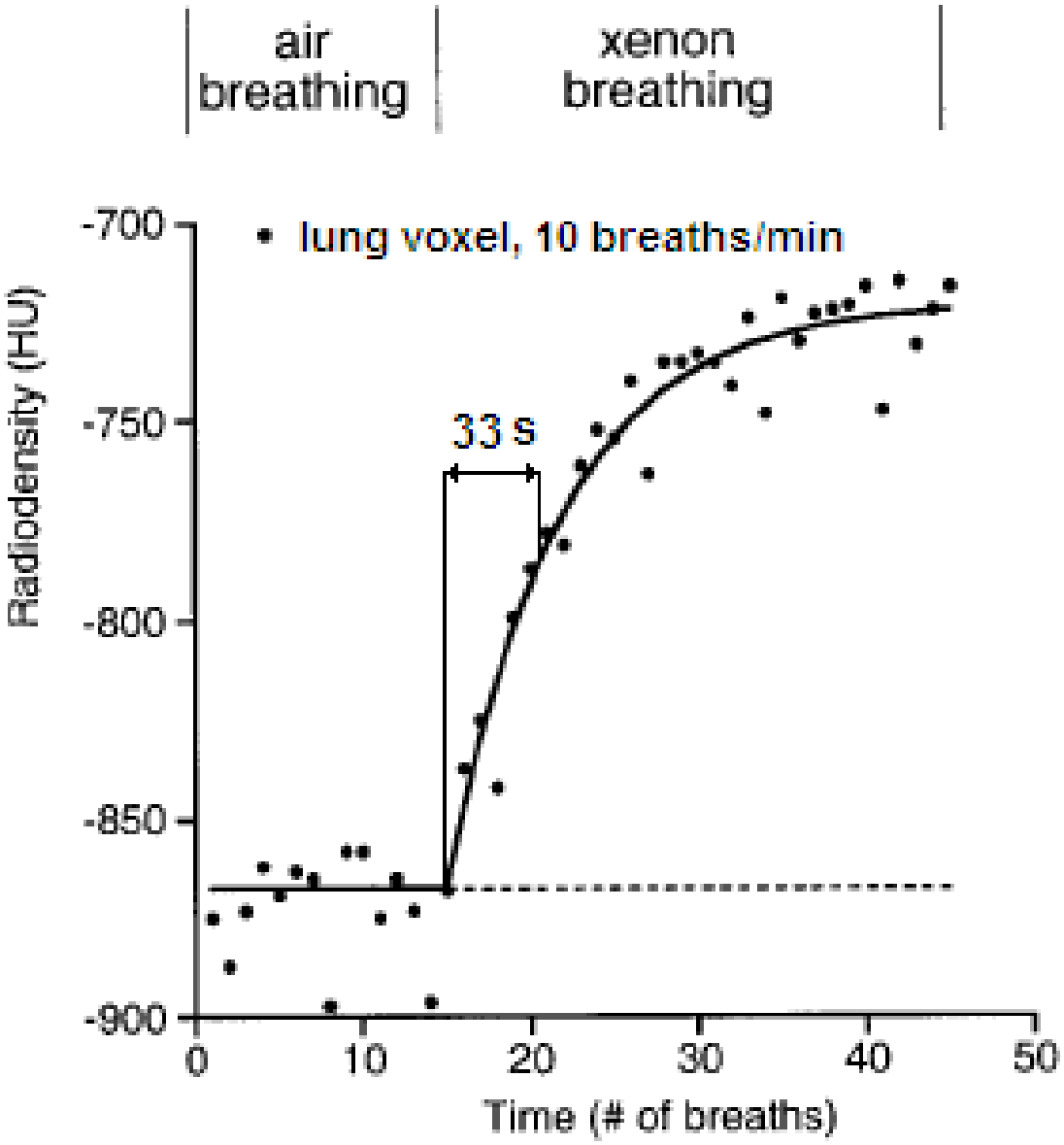
halveringstijd N_2 max. 80 s.

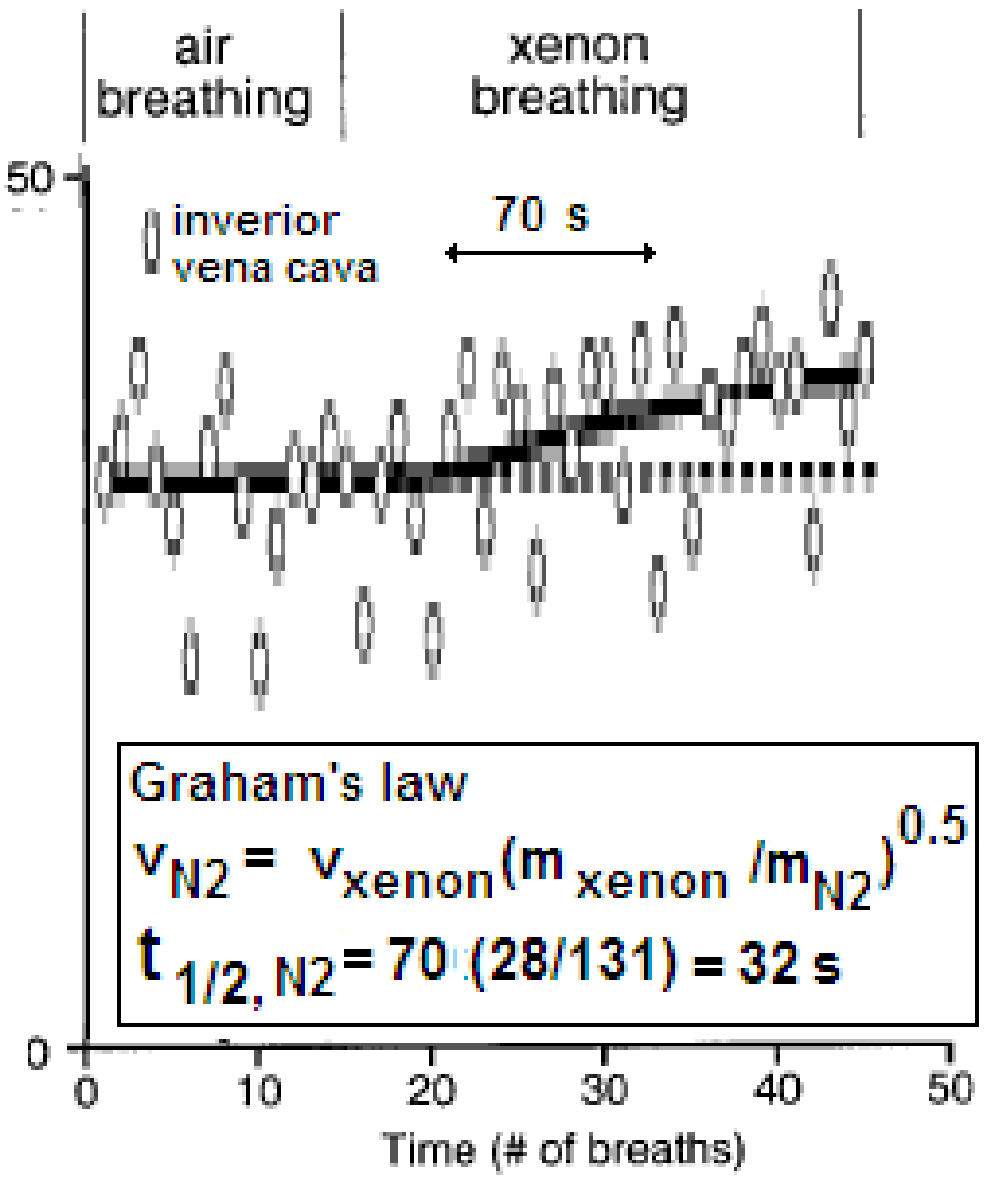
Met inspanning 40 s.

Methode 2

Pols 70/min, slagvolume 140 ml, is 10 l/min, dus 2 x rond/min. N_2 en O_2 diffunderen ongeveer even snel (√Molmassa). Dus halveringstijd heel kort: < 1 min? **Met inspanning 4x rond!**

Methode 3 Nette meting: met isotopen (Xe)





Halveringstijd bloed (opgelost) is dan:

32 + 4 (longart.) +2 (luchtwegen) = **38** s.

Halveringstijd transport N_2 bel → bloed:

is omstandigheden-bepaald, maar wel kort (mineraalwater met CO_2). Vermoedelijk seconden.

Dus totaal ca. **40 s.**

ONZIN :

No. 1 (vaak beweerd) : dat halfwaarde bloed minuten is.

Dus voor bloed is diepe stop van 2 - 4 min OK.

Twee-fase theorie zegt:

met DST totale stoptijd korter dan zonder.

Wat wijst exp. onderzoek uit?

Marroni ….. Germonpre et al.
A deep stop .....25 m dive….Undersea Hyperb Med. 2004;31:233-43.
Gevonden: **minder bellen bij diepe stop**.
Echter: bellen-effect en Haldanian effect synergistisch.

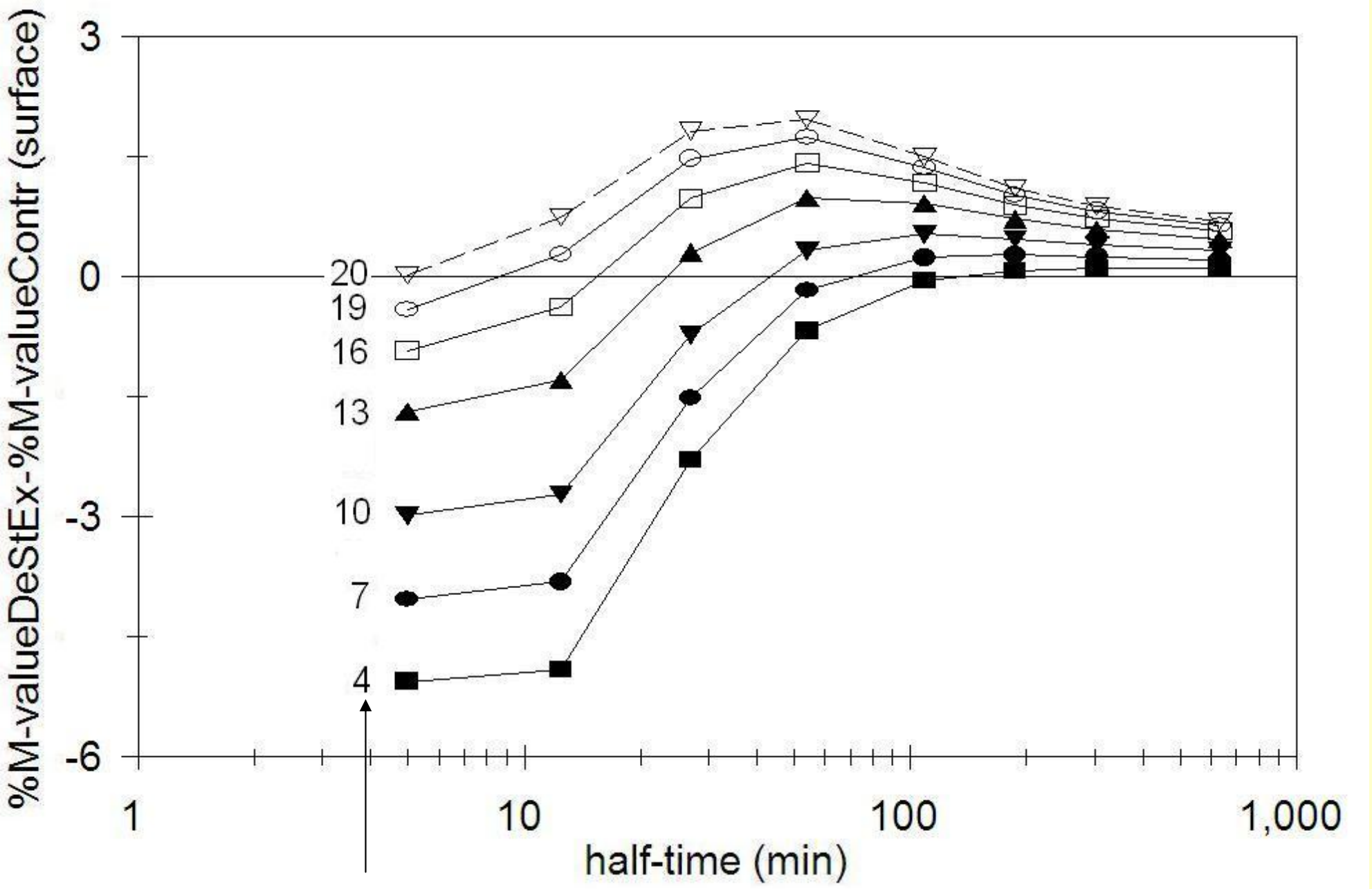
Hoe zien de zgn. **M-values (kritische drukken**) eruit van de profielen?

•M-value = maximale pN2 op actuele diepte bij gekozen stopdiepte.

•NB bedenk: de (Buhlmann) **M-values zijn zuiver empirisch** (gebaseerd op DCI incidentie) dus houden impliciet rekening met ontstaan bellen!!

•ONZIN no. 2: de bewering dat deze M-values alleen berusten op de opgeloste fase.

%M-value ≡100% x momentaneous $P_{comp\ N2}$ /M-value (ref absolute pressure).



MDD 20 msw, 40 min

diepte
diepe stop
(4 min)

Marroni ….. Germonpre et al.
A ~~deep stop .....25 m dive~~….Undersea Hyperb Med. 2004;31:233-43.
Verkeerde opzet: conclusie triviaal en niets-zeggend over effect diepe stop.

ONZIN no. 3: te beweren dat bij toevoegen diepe stop het minder optreden van bellen (alleen) een bellen-effect zou zijn. Bovendien was er onder vakgenoten kritiek op de opzet van de studie en de betrouwbaarheid van de Dpler metingen.

Blateau et al.
Bubble incidence after staged decompression from 50 or 60 msw: effect of adding deep stops. Aviat Space Environ Med. 2005;76:490-2. Bij toevoegen diepe stop zelfs meer bellen!

Andere artikelen niet ‘conclusive’.

Marroni ….. Germonpre et al.
A deep stop .....25 m dive….Undersea Hyperb Med. 2004;31:233-43.
Verkeerde opzet (toevoegen diepe stop; bellen-effect en Haldanian effect synergistisch) waardoor het geen ondersteuning is voor houden diepe stop (Letter to editor van Brubbak c.s.).

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Conclusie : controversieel of onbruikbaar.

Dan zelf doen!

Bubble formation after 20-m dive: deep-stop vs. shallow-stop decompression profiles

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en vele (NVD) vrijwilligers

Bubble Formation After a 20-m Dive: Deep-Stop vs. Shallow-Stop Decompression Profiles

NICO A.M. SCHELLART, JAN-JAAP BRANDT CORSTIUS, PETER GERMONPRÉ, AND WOUTER STERK

SCHELLART NAM, BRANDT CORSTIUS J-J, GERMONPRÉ P, STERK W. *Bubble formation after a 20-m dive: deep-stop vs. shallow-stop decompression profiles*. Aviat Space Environ Med 2008; 79:488–94.

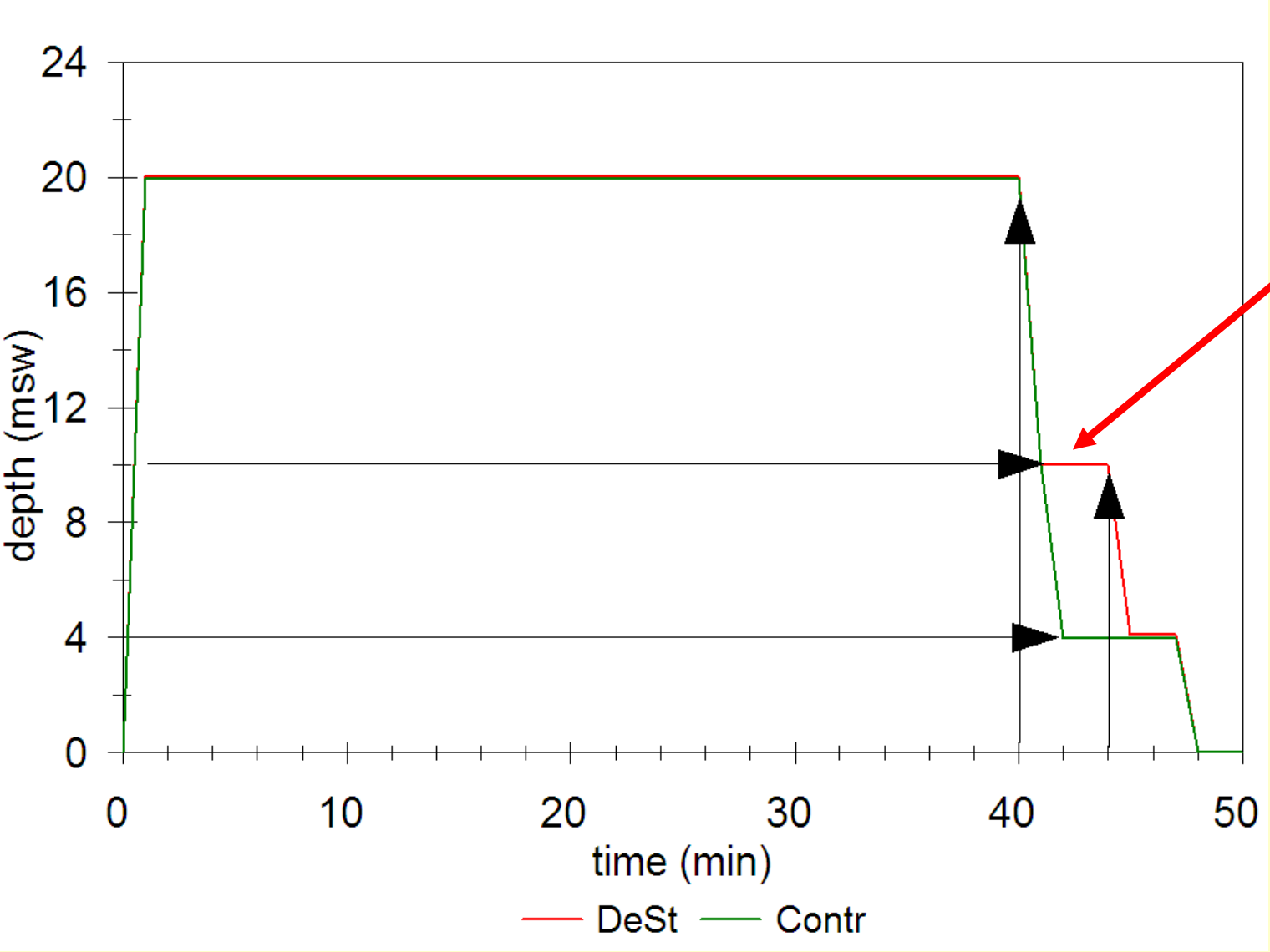
Objectives: It is claimed that performing a "deep stop," a stop at about half of maximal diving depth (MDD), can reduce the amount of detectable precordial bubbles after the dive and may thus diminish the risk of decompression sickness. In order to ascertain whether this reduction is caused by the deep stop or by a prolonged decompression time, we wanted to test the "deep stop" theory without increasing the total decompression time. From a modeling point of view, Haldanian theory states that this situation would increase the probability of observable bubbles, because of a longer stay at depth. Under these conditions, we examined whether a "deep-stop dive" (DSD) produces more bubbles or less than a "shallow-stop dive" (SSD). ***Methods:*** Recreational divers performed either a DSD or a SSD. Both groups were matched biometrically. MDD was 20 msw, bottom time 40 min and total diving time 47 min. In DSD, the "deep" stop (10 msw) replaced 3 min of the 7 min stop at 4 msw of SSD. ***Results:*** DSD produced significantly more precordial bubbles than SSD after knee bends (*P*-values ranging from 0.00007 to 0.038). ***Discussion:*** Our results indicate that at least for the tested dive profile, the higher supersaturations after surfacing overruled any possible beneficial effects of the deep stop on bubble formation. The usefulness of substituting a shallow stop with a deep stop in dives up to 20 msw can be questioned; at the least, more research is needed.

Keywords: diving, shallow stop, deep stop, VGE, bubble grade, decompression theory.

IN RECENT YEARS, several investigators of decompression theory have solved N_2 (single-phase models such as Haldanian models) (2,7). Although Haldanian models are formal descriptions (black box models) of complex physiology, they help to design experiments, formulate hypotheses, and may help with evaluating experimental results.

In the theory of bubble dynamics, at the depth of the deep stop the inward pressure gradient between the expanded bubble and surrounding tissue is reduced compared to that at the decompression ceiling. A small gradient is supposed not to result in N_2 transport (14). At the end of a deep stop, the bubble may even release some gas due to off-gassing of a surrounding fast tissue. Going directly to the decompression ceiling will result in N_2-uptake by the bubble when the tissue bubble pressure gradient is sufficiently large (15,18). In the dual phase theories such as the Varying Permeability Model (VPM) (18), assuming a surfactant monolayer around the bubble, the direct ascent may result in incorporation of new surfactant molecules in the monolayer, since the increase of strain in the monolayer is too large. This results in extra uptake. On the basis of these mechanisms, VPM theory predicts that dives with a deep stop allow shortening of the shallow stop(s), resulting in a shorter or at most equal total ascent time (7,15–18).

The dive profiles



What happens when a (part of the) shallow stop is replaced by deep stop, the original intention of the deep stop approach?

Hal M:

more N_2 uptake in non-saturated compartments →

higher saturations → more bubble grow during and after ascent.

Unsaturated compartments: less release.

Dual-phase (bubble) M:

less bubble grow during ascent and later.

So, the both models have **counteracting effects**.

Resuming:

•HalM and Dual-phase M counteract.

•Literature is conflicting, indicating that reducing grow will be small??

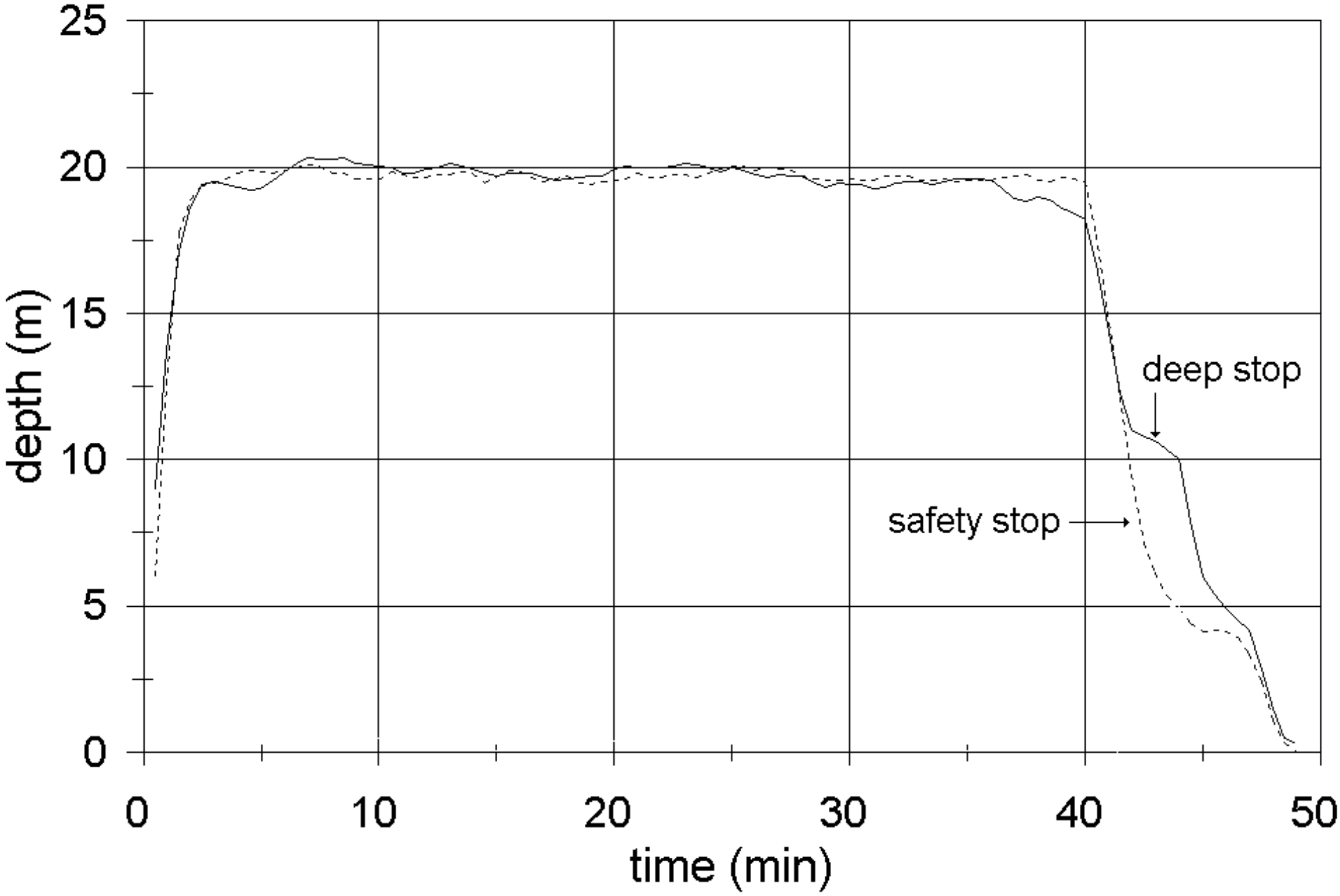
•MDD chosen for our experiment is only 20 msw, which surmizes that the effect is possibly small.

•The Hal. Model effect may cancel or overrule the deep stop effect of Dual-phase M.

This all leads to the hypothesis:

DSD produces more or as much VGE bubbles as control dive (SSD).

gemiddelde profielen DSD en SSD



oppervlakte interval 2h30min.

Subjects For practical reasons the experiments were performed by two groups of divers: one performed DSD and the other SSD.

Biometrical characteristics	**DeSt**	**Contr**		
characteristic	**m±SD or 25, 50 and 75 percentile**	**m±SD or 25, 50 and 75 percentile**	**relative difference of means DeSt − Contr (%)**	**P of t test or KS test, double sided**
male / female	**16 / 2**	**10 / 4**		
age (year)	**52.4 ± 9.7**	**53.3 ± 11.9**	**-1.7**	**0.82**
BMI (kg/m²)	**25.5 ± 4.0**	**26.4 ± 4.4**	**-3.6**	**0.54**
body fat Omron	**22.9 ± 8.2**	**26.4 ± 7.4**	**-14.2**	**0.21**
body fat skin folds	**27.9 ± 7.3**	**30.5 ± 7.0**	**-9.0**	**0.32**
hours endurance sport/week	**1.5 2.5 5.62**	**0 2 4.25**		**0.14**
Psys, rest (mmHg)	**130 ± 16.2**	**128 ± 14.0**	**1.5**	**0.72**
Pdias, rest (mmHg)	**85 ± 8.8**	**82 ± 8.7**	**3.4**	**0.36**
HRrest	**60.8 ± 9.2**	**64.1 ± 7.2**	**-5.3**	**0.28**
dive experience (year)	**6 8 27.5**	**7.75 9 24.2**		**0.85**
log # dives/year	**1.31 ± 0.36**	**1.07 ± 0.39**	**54**	**0.079**

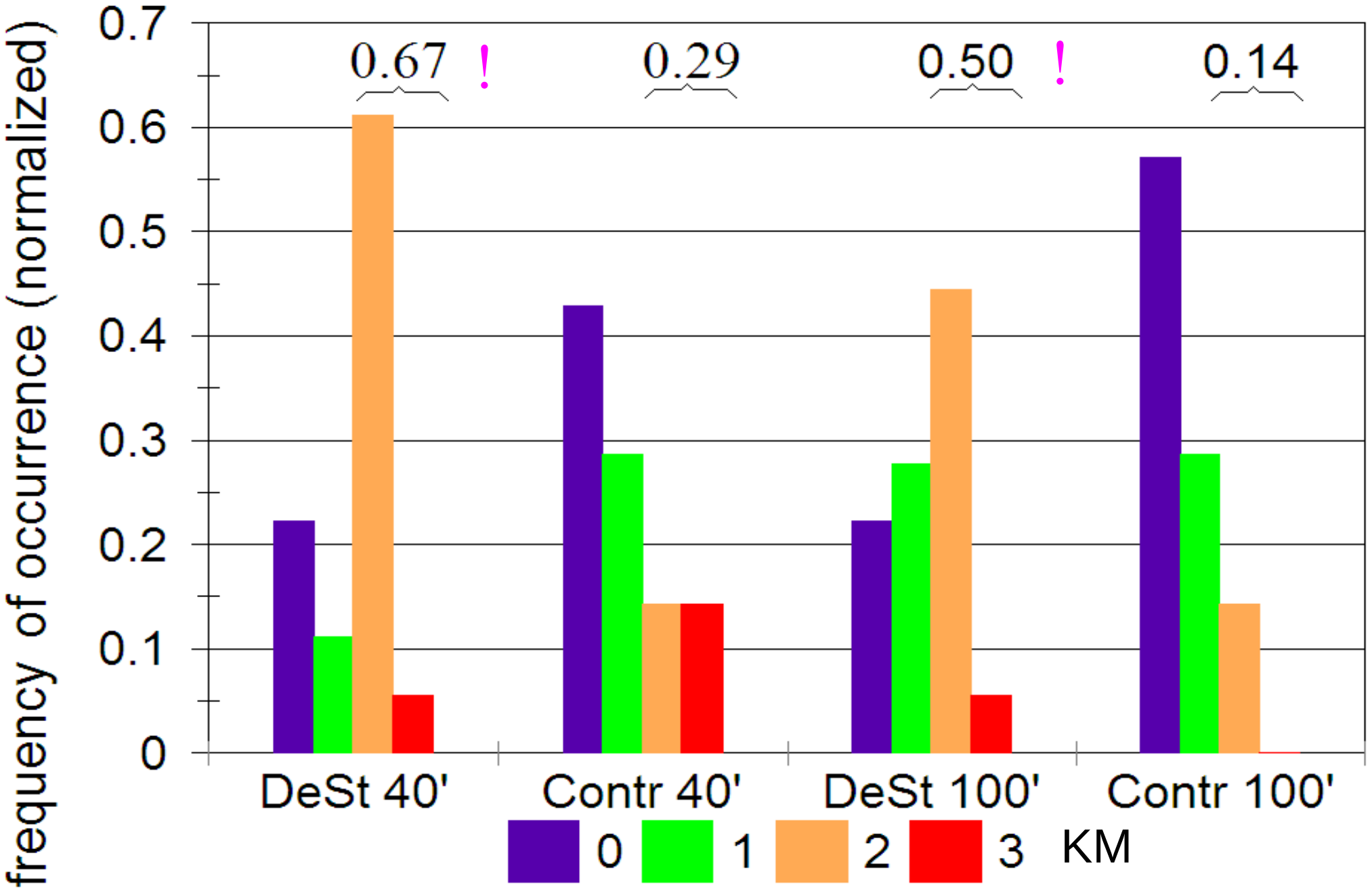
The two groups are well matched. Regarding age, body fat, sport activity, cardiovasculair characteristics and diving experience both groups are very well matched.

Bubble occurrence

Bubble grades (BGs) were measured in KM units (Kisman Masurel, an integer scale from 0 to 4),

40 and 100 min after surfacing.

KM units were transformed to Spencer units and the latter, if necessary to log number of bubbles/cm^2.



DeSt seems to produce **more** VGE bubbles

Results of statistical tests

Rest			
test	**data**	**Datasets**	**P**
Yates Cochran	Spencer	DSD versus SSD, pooled values	*0.11*
Flex			
Yates Cochran	Spencer	DSD40 versus SSD40	*0.085*
Yates Cochran	Spencer	DSD100 versus SSD100	**0.010**
Yates Cochran Hotteling correction	Spencer	DSD versus SSD, pooled values	**0.019**
KISS	Spencer	DSD versus SSD	*0.085*
Mixed models unstuctured	Spencer	DSD versus SSD, pooled values	**0.011**

DSD produces more, not less bubbles.

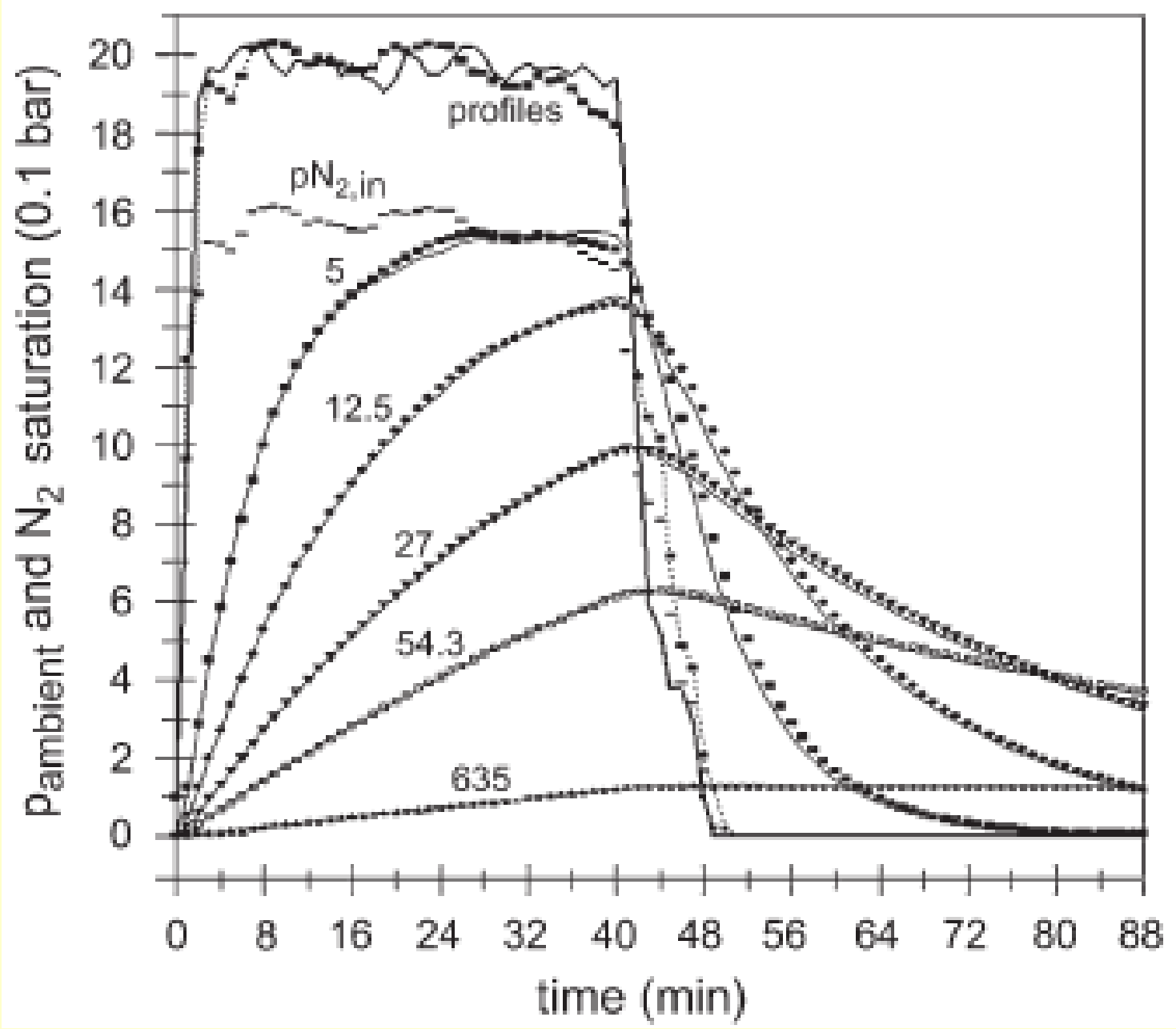
Can we understand these results?

An attempt.

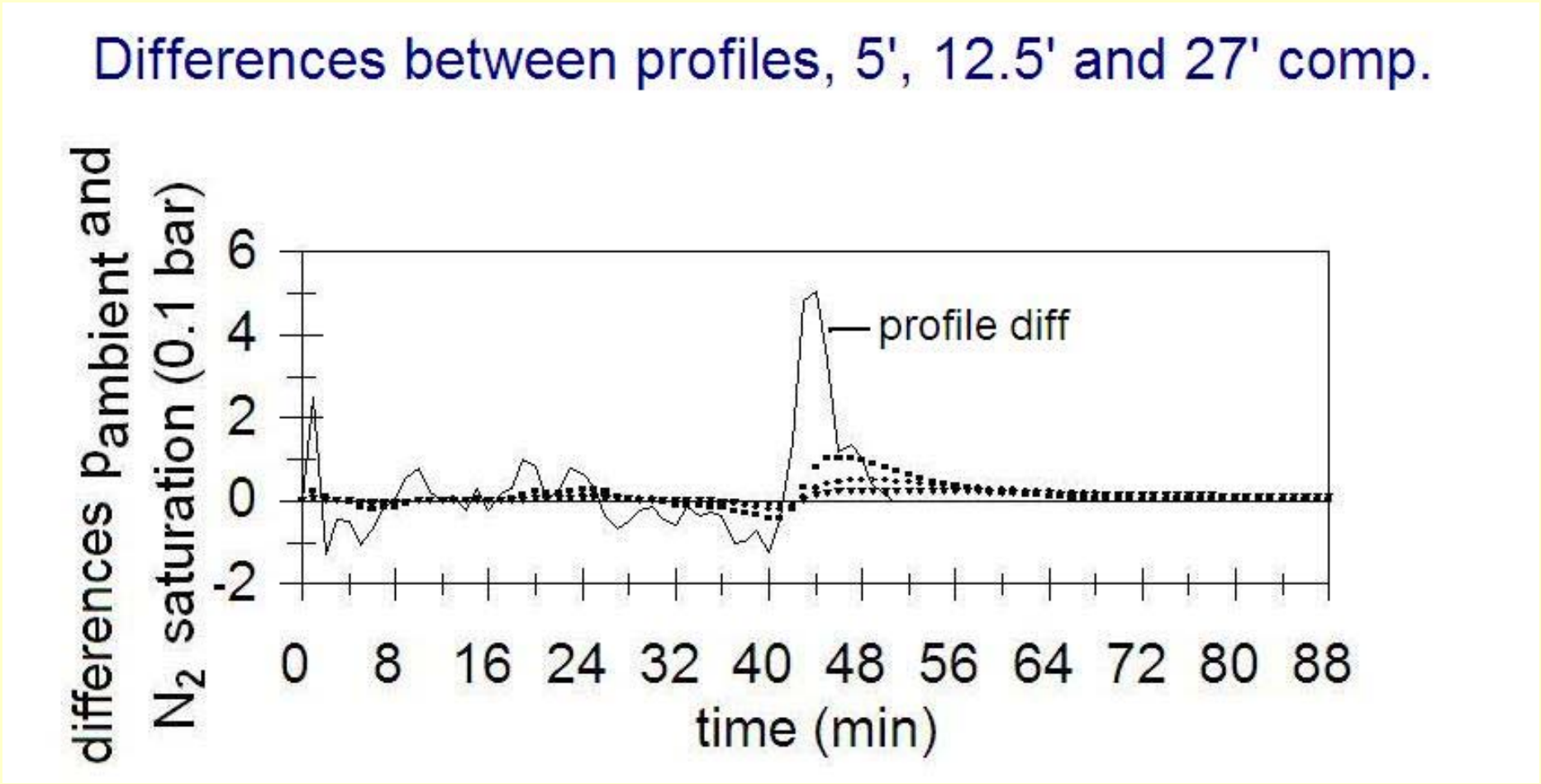
For this, the nitrogen saturations and %M-values* of DSD versus SSD, and their differences will be calculated in accordance with Bühlmanns ZH-L16C model, and evaluated.

* %M-value ≡100% x momentaneous $P_{comp\ N2}$ /M-value

(ref absolute pressure).

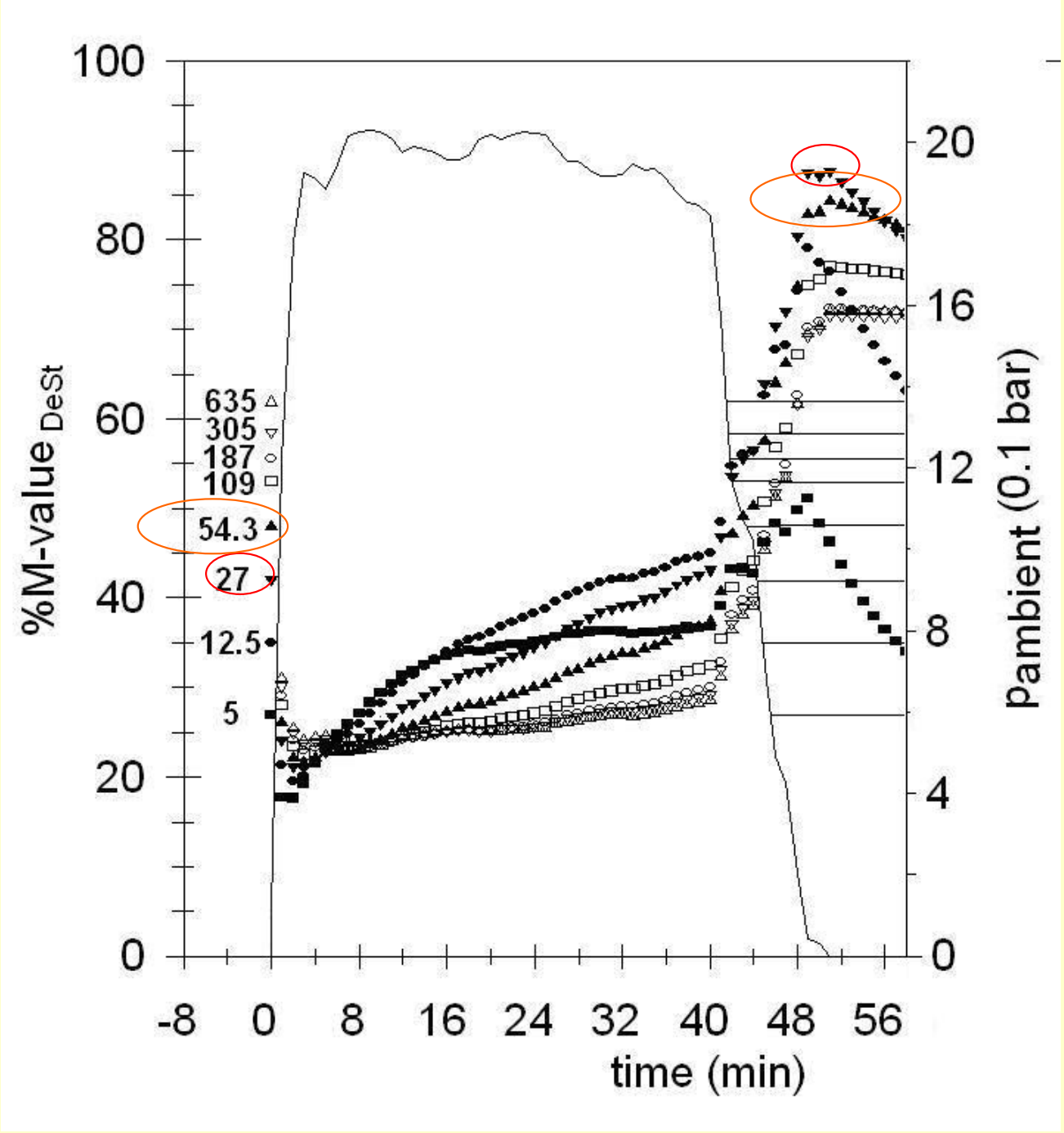


The higher the halftime, the smaller the difference.



5 min compartment shows during the last part of the 4 msw stop and after surfacing a difference of 0.12 bar.

%M-values



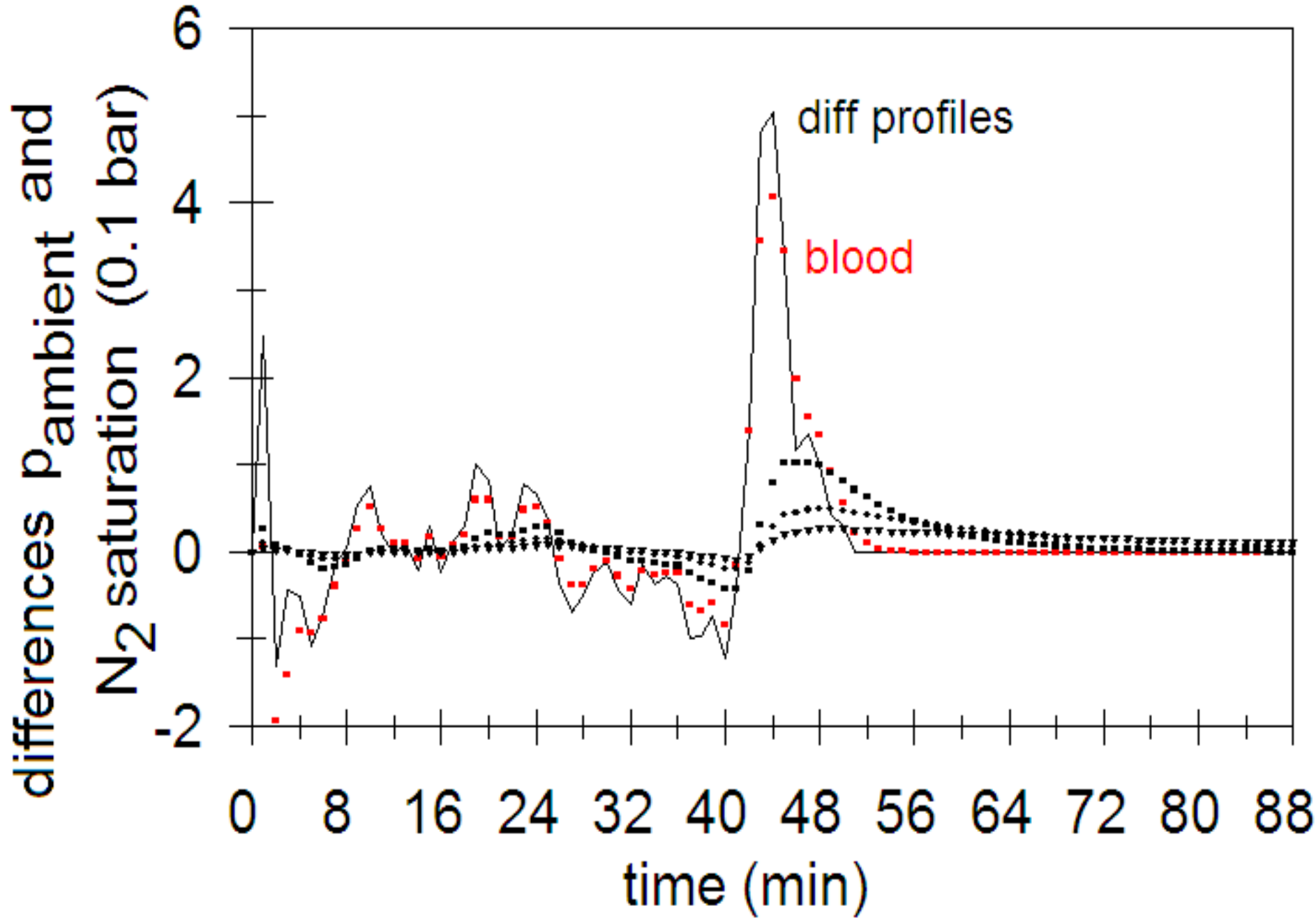
During **bottom** stay: %M-values are **too small to give bubble grow**. After surfacing: especially the **27** (+6%) and **54** (+4%) compartment will show bubble grow.

The dilemma

Bubbles were not measured in the 27’ and 54’ compartment. Only their %M-values can be calculated.

VGE bubbles were measured in the blood (precordially).

Halftime of blood is ca. 40 s, but the **M-value blood is unknown**.



Difference of blood saturation between DSD and SSD. $p_{N2,blood}$ nearly follows $p_{N2,inspired}$

Stel, M-value bloed = 2, dus pN_2 mag absolute druk gehalveerd worden.

Van 20 m (3 bar) naar 4 m (1,4 bar) toegestaan, immers tijdens opstijging (duurt 1’36”) al uitwassen.

10 m stop: veel weefsels worden verder opgeladen, waardoor meer pN_2 en bellen in deze weefsels na surfacing.

In bloed **competitie tussen bellen en opgeloste fase** om de N_2 release vauit weefsels. Bij diepe stop kunnen de VGE-bellen dan beter groeien. NB **belvolume/opgelost = 0.0001-0.001**.

Is dit de hypothetische verklaring onze 20 m 40 min resulaten?

Wienke and O'Leary
Statistical correlations and risk analyses techniques for a diving dual phase bubble model and data bank using massively parallel supercomputers. Comput Biol Med. 2008;38:583-600.

Weinig overtuigend voor luchtduiken, want resultaten controlle profielen niet behandeld.

Marroni ….. Germonpre et al. Effect of varying deep stop times and shallow stop times on precordial bubbles after dives to 25 msw (82 fsw). Undersea Hyperb Med. 2007 Nov-Dec;34:399-406.

25 m, 25 min, diepe **stop op 15 m** en stop op 6 m
25 m, 25 min, alleen **stop op 6 m,** DT gelijke duikduur.
15 m stop duik gunstig t.o.v. **6 m stop duik** , maar alleen indien:
- stopduur 6 m tenminste zolang als die op 15 m
- stopduur 15 m tenminste 2,5 min.

Verklaring:
bij **6 m stop duik** groeien bellen door Δdiepte van 19 m.
Niet bij **15 m stop duik** op 15 m door te kleine Δdiepte van 10 m.

Of combinatie 6-15 m **optimaal** is, is onwaarschijnlijk.

Conclusion

By replacing a shallow stop by a deep stop, Bubble Grade may be increased or diminished.
This is dependent on the exact profile!

For dives with MDD < 25 m, the deep stop is possibly not benificial, neither for dives > 45 m.

ONZIN No. 4: de bewering dat een diepe stop ter vervanging van ondiepe stop altijd beter is.

Echter: fysiologisch (gasholtes) en psychologisch (alles OK?) 1-2 stoppen bij diepe duik OK.

De Diepe Stop;
Zin en Onzin

???