The diving medical detectives: when diving medicine books are completely wrong 17.09.2021, Part II

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Abstract / Methods / Results:
as per Part I:

DOI: 10.13140/RG.2.2.15199.79528

Severe errors are appearing more frequently in monographs. Omnibus Volumes, written by teams of experts, are obviously more resilient to errors.

Discussion / Recommendations:
Single authors / editors should consult with expert teams prior to publication.

If you want to contribute s.th. to our list, we would be very happy if you send an e-mail to our head of lab: director@smc-de.com

(That is: to be continued with Part III ☺)

→ [75]

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p. 60, Fig. 4-10 bottom; maybe, this is not a real, severe error, but the original manual from the ORCA Edge® (LHS) does not mention any „Experience“. The „Edge“ was coined by Dan Orr, as an „Electronic Dive Guide“ …

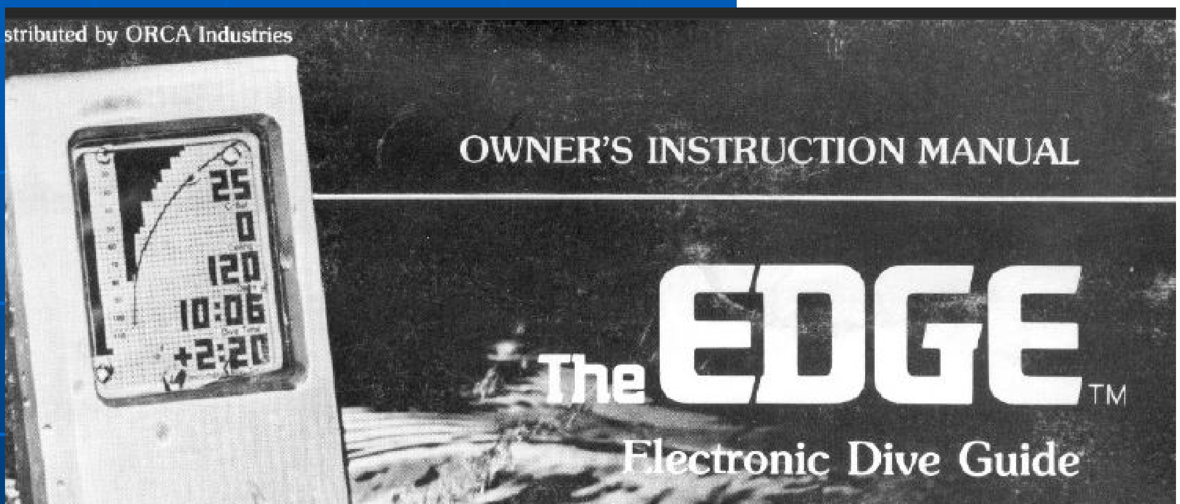

Figure 4–10. *A.* The Orca EDGE (Electronic Dive Guide Experience), the first commercially successful digital dive computer. The display of the EDGE had a bar graph that represented the computed nitrogen tension (in fsw) in each of 12 Haldane tissues.

Since this was an eyecatcher for us, we decided to scrutinize this page in-depth, and found more …

→ [75], continued

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p. 60, top, Tables 4-1 & 4-2; if you ignore the somewhat misleading legend (LHS) then table 4-1 is self-consistent: if you start with the M_0-values in row 4, divide these by 33 you get the Tissue ratios in row 3, dividing these ones by .79 you get the Haldane ratios in row 2:

Table 4–1. Definitions and examples of safe-ascent criteria based on supersaturation*

	Tissue Half-Time (min)					
	5	**10**	**20**	**40**	**80**	**120**
Haldane ratio = $P_{N2}/(0.79 \times P_B)$	4	3.4	2.75	2.22	2	2
Tissue ratio = P_{N2}/P_B	3.15	2.67	2.18	1.76	1.58	1.55
M-value (fsw) = ratio × (D_{next} + 33 fsw)	104	88	72	58	52	51

*The M-value shown is for ascent directly to the surface from depth. See text for further discussion.

Table 4–2. M-values for ascent in increments of 10 fsw

Safe Ascent Depth (fsw)	M-Values: Tissue Half-Time (min)								
	5	**10**	**20**	**40**	**80**	**120**	**160**	**200**	**240**
0	104	88	68	46	38	35	34	34	33
10	120	98	78	56	48	45	44	44	43
20	130	108	88	66	58	55	54	54	53
30	140	118	98	76	68	65	64	64	63
40	150	128	108	86	78	75	74	74	73
50	160	138	118	96	88	85	84	84	83

→ [75], continued

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p. 60, top, Table 4-2; the M_0 values from Table 4-1 should then appear in Table 4-2 as the 2nd. row, i.e. SAD = D_{next} = 0; this is OK for HT 5 & 10 min (yellow display). But for the HT 20 to 120 min these M_0 do not match. Especially the M_0 with 33 fsw for HT 240 min would imply zero-supersaturation: a little bit annoying for real-world diving…

60 **Chapter** 4 Inert Gas Exchange and Bubbles

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10	120	98	78	56	48	45	44	44	43
20	130	108	88	66	58	55	54	54	53
30	140	118	98	76	68	65	64	64	63
40	150	128	108	86	78	75	74	74	73
50	160	138	118	96	88	85	84	84	83

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→ [75], continued

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On p. 59 it is insinuated that these M-values have something to do with the US Navy.

But by comparison with the ultimate source on M-values, i.e. Bob Workmans NEDU Report 6-65 [a]; on p. 31 we found that neither **all the M-values** (2nd. column, D = 10 ft.) as such and as well, nor **the ΔM** match, i.e. the Tables 4-1 & 4-2 are, to put it mildly, only partially useful to the inclined reader.

Table of Maximum Allowable Tissue Tensions (M) of Nitrogen for Various Half-time Tissues

Depth of decompression stop

D (ft)	10	20	30	40	50	60	70	80	90	100
A (ft)	43	53	63	73	83	93	103	113	123	133
H (min)	(M) (Feet of sea water equivalent)									
5	104	122	140	158	176	194	212	230	248	266
10	88	104	120	135	152	168	184	200	216	232
20	72	87	102	117	132	147	162	177	192	207
40	56	70	84	98	112	126	140	154	168	182
80	54	67	80	93	106	119	132	145	158	171
120	52	64	76	88	100	112	124	136	148	160
160	51	63	74	86	97	109	120	132	143	155
200	51	62	73	84	95	106	117	128	139	150
240	50	61	72	83	94	105	116	127	138	149

ΔM/Δ10 feet depth

H (min)	5	10	20	40	80	120	160	200	240
ΔM(ft)	18	16	15	14	13	12	11.5	11	11

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...IG

→ [4], [4a], [5], [5a], [65], [234]:

In part I we promised to have a look at our collection of Albert Alois Bühlmanns most prominent books.

→ [4], [4a], [5], [5a], [65], [234]

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Basis of the following slides # 8 - 14 are the presentations of Albi,
pls. cf. the references [b] & [c].

→ [234] & [4]:

Since [234] is the english version of [4], it should be an exact translation:
It is not.

The a-& b-coefficients for the ZH-L_{12} differ for a couple of the compartments, (# 3, 7, 10 → 16; red display on the next slide) and, thus, a couple of the calculated run-times and decompression table comparisons diverge between the 2 books (for eg. p. 31).

An a-posteriori validation, like the one we did in **[c],** will therefore not work.

[234] finds the ZH-L_{12} set on p. 27, in [4] on p. 27; pls. cf. the next 2 slides:

→ [234], p.27:

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Table 8. ZH-L_{12}. Twelve pairs of coefficients for 16 half-value times for helium and 16 half-value times for nitrogen

Compartment	1	2	3	4	5	6	7	8	9
He-½ t (min)	1	3	4.6	7	10	14	20	30	43
N_2-½ t (min)	2.65	7.94	12.2	18.5	26.5	37	53	79	114
Factor a, He, N_2	2.200	1.500	1.080	0.900	0.750	0.580	0.470	0.455 (8–9)	
Factor b, He, N_2	0.820	0.820	0.825	0.835	0.845	0.860	0.870	0.890 (8–9)	

Compartment	10	11	12	13	14	15	16
He-½ t (min)	55	70	90	115	150	190	240
N_2-½ t (min)	146	185	238	304	397	503	635
Factor a, He	0.515 (10–11)		0.515	0.515 (13–16)			
Factor b, He	0.926 (10–11)		0.926	0.926 (13–16)			
Factor a, N_2	0.455 (10–11)		0.380	0.255 (13–16)			
Factor b, N_2	0.934 (10–11)		0.944	0.962 (13–16)			

If both helium and nitrogen are present in the compartments, factors a and b must be calculated in correspondence with the proportion of the gases, as in the example for compartments 13–16:

a $(He+N_2)=[(P_{He}\cdot 0.515)+(P_{N_2}\cdot 0.255)]/[P_{He}+P_{N_2}]$;

b $(He+N_2)=[(P_{He}\cdot 0.926)+(P_{N_2}\cdot 0.962)]/[P_{He}+P_{N_2}]$.

• Values deviate from german original, p. 27, Table 8 [4] !

→ [4], p. 27:

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Tabelle 8. ZH-L_{12}. 12 Faktorenpaare für 16 Helium- und Stickstoffhalbwertszeiten

Kompartiment	1	2	3	4	5	6	7	8	9
He-$\frac{1}{2}$ t, min	1	3	4,6	7	10	14	20	30	43
N_2-$\frac{1}{2}$ t, min	2,65	7,94	12,2	18,5	26,5	37	53	79	114
Faktor a, He, N_2	2,20	1,50	1,05	0,90	0,75	0,60	0,45	0,43 (8–9)	
Faktor b, He, N_2	0,820	0,820	0,825	0,835	0,845	0,860	0,870	0,890 (8–9)	

Kompartiment	10	11	12	13	14	15	16
He-$\frac{1}{2}$ t, min	55	70	90	115	150	190	240
N_2-$\frac{1}{2}$ t, min	146	185	238	304	397	503	635
Faktor a, He	0,47 (10–11)		0,47	0,47 (13–16)			
Faktor b, He	0,925 (10–11)		0,925	0,925 (13–16)			
Faktor a, N_2	0,43 (10–11)		0,35	0,23 (13–16)			
Faktor b, N_2	0,931 (10–11)		0,943	0,962 (13–16)			

Befinden sich in den Kompartimenten gleichzeitig He und N_2, müssen die Faktoren a und b entsprechend Gasanteilen berechnet werden:

Beispiel Kompartimente 13–16:
a $(He + N_2) = (pHe \cdot 0{,}47) + (pN_2 \cdot 0{,}23)/(pHe + pN_2)$,
b $(He + N_2) = (pHe \cdot 0{,}925) + (pN_2 \cdot 0{,}962)/(pHe + pN_2)$

→ [65], p. 158, pls. cf. next slide:

The b-coefficient of compartment # 4 (HT= 18.5 min) is 0.7825 (yellow display).

By using AAB‘s own formula to derive the a- & b-coefficients from the HT (formula ibd. on p. 129) it should be 0.7725

For real-world diving this is fortunately positive:
the tolerated inert-gas pressure $p_{t,tol}$ goes down from ca. 2.05 to ca. 2.03 Bar

As well for compartment # 5 the b-value, derived by the formula on p. 129, is 0.81254991 (= 0.8125) but here rounded up to 0.8126 (red line).

→ [65], p. 158:

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Tabelle 25. Die Koeffizienten ZH-L16 für N_2

Kompartiment Nr.	$t_{1/2}$ N_2 [min]	ZH-L16A „theoretisch" b	ZH-L16A „theoretisch" a	ZH-L16B Tabelle a	ZH-L16C Computer a
1	4,0	0,5050	1,2599	1,2599	1,2599
1 b	5,0	0,5578	1,1696	1,1696	1,1696
2	8,0	0,6514	1,0000	1,0000	1,0000
3	12,5	0,7222	0,8618	0,8618	0,8618
4	18,5	0,7825	0,7562	0,7562	0,7562
5	27,0	0,8126	0,6667	0,6667	0,6200
6	38,3	0,8434	0,5933	0,5600	0,5043
7	54,3	0,8693	0,5282	0,4947	0,4410
8	77,0	0,8910	0,4701	0,4500	0,4000
9	109,0	0,9092	0,4187	0,4187	0,3750
10	146,0	0,9222	0,3798	0,3798	0,3500
11	187,0	0,9319	0,3497	0,3497	0,3295
12	239,0	0,9403	0,3223	0,3223	0,3065
13	305,0	0,9477	0,2971	0,2850	0,2835
14	390,0	0,9544	0,2737	0,2737	0,2610
15	498,0	0,9602	0,2523	0,2523	0,2480
16	635,0	0,9653	0,2327	0,2327	0,2327

→ **[65], p. 114:**
instead of 1.1 → 1.24

→ **[65], p. 119:**
instead of the old ZH-L coefficients; with the 50:50 balanced new ones (0.3723 & 0.946) it should read 0.9968

→ **[65], p. 12, Tabelle 1:**
for 1 Bar *inspired air* the Vol.-% of N_2 & O_2 do not match (col. 3); it seems rather like alveolar air …

the conversion factor from 1 Bar = 750.06 mm Hg seems odd, since the 1st. diver-ballpark yields 760/1013 = 750.24.
750.2 is used in all standard references, i.e.: **[62], [63], [75], [178].**

By consulting the ultimate source for diving physicians on pressure-conversions **[110]** on p. 893, Table A-3, there yields as well:

$$1 \text{ mm Hg} = 1.33323 * 10^{-3} \text{ Bar}$$

→ [65], p. 146, Tabelle 22:
for this SAT-dive on air to 30 m the $p_{inert, max}$ is ca.
4 * 0.8 = **3.2** and not 3.6 Bar.

Either this table was calculated with another mix, which is not indicated, or to another depth (37 m @ air), which is not indicated as well.

However, a SAT dive with air to 36.8 m fresh water would yield the used p_{inert} 3.6 Bar; the decompression-time with 54 h on air, starting @ 23 m could be confirmed via DIVE **[d],** pls. cf. the attachment, slide #17. Because this example SAT dive has a long history, starting with [4] in 1983, we assume, that the then published ZH-L_{12} has been used to create Table 22 and not the new ZH-L 16 from [65].

→ [65], p. 189, Tabelle 31:

(only for the sake of completeness: the entries at Nr. 2 do not match the cited source from DAN / DSL)

References:

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[a] Workman, R.D. (26 May 1965) Research Report 6-65, Calculation of Decompression Schedules for Nitrogen-Oxygen and Helium-Oxygen Mixtures, USN NEDU, AD #620-879

[b] Salm, Albi (August 2021) Dekompression: Kapitel 14, S. 368 - 372: Fehlerchen im Bühlmann Konvolut

[c] Salm, Albi (October 2020) ZH-L_{12} : Validation of an old (1982) experimental Heliox jump dive (30 m, 120 min); DOI: 10.13140/RG.2.2.24608.20482/1

[d] Rosenblat, Miri; Vered, Nurit (07 / 2021) PoC for DIVE Version 3_10, http://dx.doi.org/10.13140/RG.2.2.28123.69924

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[75] "Bove and Davis' DIVING MEDICINE", Alfred A. Bove, 4 th. edition, Saunders 2004, ISBN 0-7216-9424-1

[110] The Underwater Handbook: A Guide to Physiology and Performance for the Engineer; Shilling, Werts, Schandelmaier; Plenum Press N.Y., 1976, ISBN 0-306-30843-6

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[4] Dekompression - Dekompressionskrankheit, A. A. Bühlmann 1983, ISBN 3-540-12514-0

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[5] Tauchmedizin (Barotrauma, Gasembolie, Dekompression, Dekompressionskrankheit) A. A. Bühlmann, Springer, 1993, ISBN 3-540-55581-1

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[65] "Tauchmedizin.", Albert A. Bühlmann, Ernst B. Völlm (Mitarbeiter), P. Nussberger; 5. Auflage in 2002, Springer, ISBN 3-540-42979-4

[234] Bühlmann, Albert Alois (1984) Decompression - Decompression Sickness, Springer, ISBN: 3-540-13308-9, 0-387-13308-9, e-book 978-3-662-02409-6

Attachment: the SAT dive with DIVE 3_10

→ Adjusting P_{amb} to 1,000 mbar:

„L“ „1.0“

→ Loading the 1983 (german) ZH-L_{12} N_2-coefficients **(Δ)**:

„NC“ „8“

→ Input of the SAT profile, depth = 36.8 m, time 6000 min:

„d“ „36.8“ „6000.“

→ Check of decompression:

„a“

yields →

The ceiling with 22.73 m and the TTS 3,241 min / 60 = 54.02 h confirm [65], p. 146, Tabelle 22.

(Δ): with the new ZH-L 16 coefficients the TTS is ca. 61 h

```
D3_10 - [Graphic1]
 was jetzt?a
maximale Ceiling:  22.73
Vorschlag Haldane 2:1 [m] =  13.40
Vorschlag Hills, B. A.: DEEP STOP [m] =    29
PDIS fuer TAU = 10 min:  36.80 [m]
PDIS fuer TAU = 20 min:  36.80 [m]
PDIS fuer TAU = 30 min:  36.80 [m]
Eingabe der Austauchstufe in Metern & cm:(m.cm):
          Austauchstufe ist zu hoch:
          niedriger wie Ceiling waehlen!
 Deko Prognose:
  24m Stopp Prognose Dekozeit:   144.0  Komp.#: 16
  21m Stopp Prognose Dekozeit:   314.0  Komp.#: 16
  18m Stopp Prognose Dekozeit:   343.0  Komp.#: 16
  15m Stopp Prognose Dekozeit:   377.0  Komp.#: 16
  12m Stopp Prognose Dekozeit:   419.0  Komp.#: 16
   9m Stopp Prognose Dekozeit:   471.0  Komp.#: 16
   6m Stopp Prognose Dekozeit:   539.0  Komp.#: 16
   3m Stopp Prognose Dekozeit:   631.0  Komp.#: 16
TTS =   3241.0
```

(un-official) Coda of Part II:

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We from the lab (Miri, Nurit & Yael) wanted urgently to push this one out to RG on the morning of 09/17, even if there is now no proof-reading & no peer-review …
This is a גוט מארגן! to a very special mensch, who happens to be our boss, presently he is on SAT in the Aegean:

בוקר טוב, אלבי;

יום הולדת שמח!

בַּקָּשָׁה

עכברי המעבדה שלך מ- TLV:

מירי, נורית ויעל

וכמו תמיד:

עד 120!

נשיקות וחיבוקים