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ZH-L_{12}: Validation of an old (1982) experimental Heliox jump dive (30 m, 120 min)

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10.13140/RG.2.2.24608.20482

Question:
Could we verify the old ZH-L_{12} decompression profile from [4], p. 35 with a topical desktop deco software?

Sources:

→ [4], p. 35

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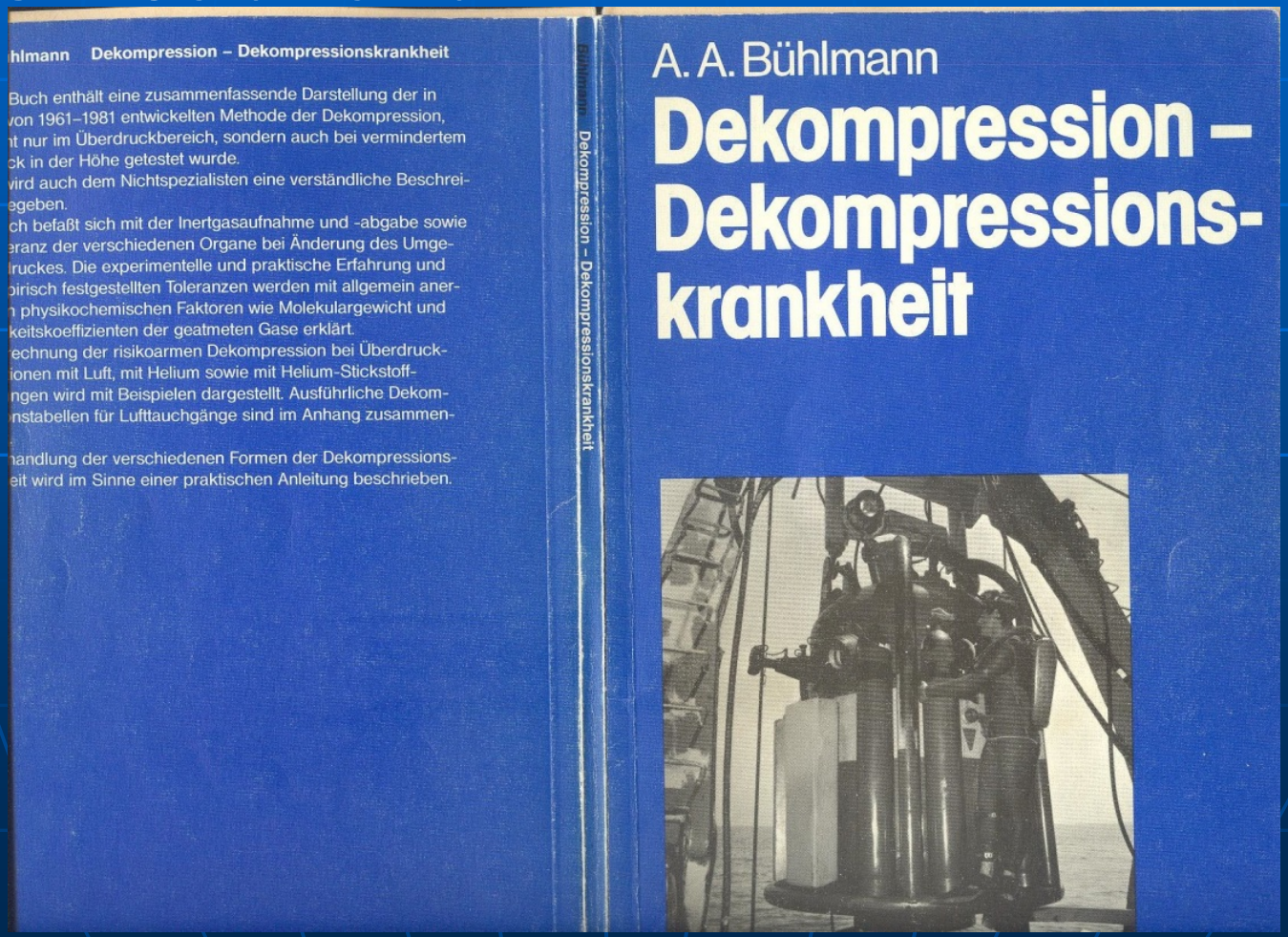
ZH-L_{12}:
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

Bühlmann, A.A. (1983): Dekompression - Dekompressionskrankheit, Springer, ISBN: 3-540-12514-0



Sources:

→ Desktop Deco Software:

DIVE Version 3

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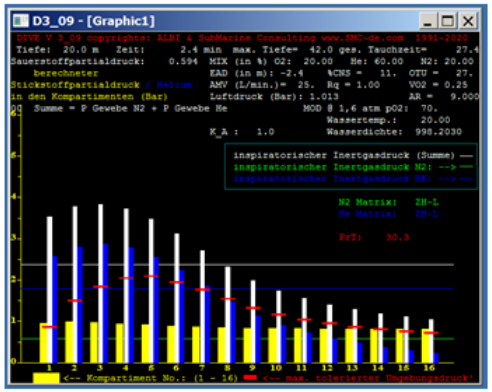
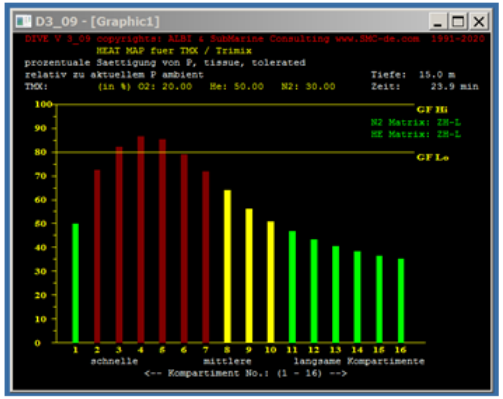
ZH-L_{12}:
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

DIVE Version 3_xx
Handbuch zur Software





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GROUP
TEL AVIV – SAN FRANCISCO – STUTTGART
WWW.SMC-DE.COM

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What is the ZH-L_{12}?

→ [4], p. 27

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ZH-L_{12}:
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

The **ZH-L_{12}** is the 1983-precursor of the ZH-L 16 decompression algorithms, used for decompression models of parallel perfused compartments.

ZH = Zuerich / Zürich, capital of Switzerland,
place of the DKL-USZ, the Hyperbaric Chamber Laboratory,
University Hospital Zürich; Albert Alois Bühlmann worked there.

L = linear; the allowed/tolerated inertgas supersaturations per compartment are simple linear equations.

12 = is not the # of compartments,
instead it is the # of **coeffcient pairs** for **both N_2 AND Helium**,
pls. cf. next slide:

The ZH-L_{12}: → [4], p. 27

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ZH-L_{12}: Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

Tabelle 8. ZH-L_{12}. 12 Faktorenpaare für 16 Helium- und 16 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
Faktor b, He, N_2	0,820	0,820	0,825	0,835	0,845	0,860	0,870		0,890

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		0,47		0,47	
Faktor b, He		0,925		0,925		0,925	
Faktor a, N_2		0,43		0,35		0,23	
Faktor b, N_2		0,931		0,943		0,962	

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 $(He + N_2) = (pHe \cdot 0{,}925) + (pN_2 \cdot 0{,}962)/(pHe + pN_2)$

ZH-L_{12}. 12 Faktorenpaare für 16 Helium- und Stickstoff-Halbwertszeiten 27

The Profile:

[4], p. 35

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ZH-L_{12}:
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

Die unterschiedlich langen Dekompressionszeiten nach einer Exposition während 120 min bei 4,0 bar mit Sauerstoff-Helium und einer geringen Kontamination des Atemgases mit N_2 zeigen Abb. 10 und Tabelle 7. Wird auf der ersten Dekompressionsstufe von Sauerstoff-Helium auf Luftatmung gewechselt, dauert die genügende Dekompression nicht 316, sondern nur 170 min. Wird anstelle von Luft 100% O_2 geatmet, so genügen 83 min. Beim Versuch CO-120 wurde nach 45 min bei vollem Druck auf Luftatmung gewechselt und anschließend die Dekompression mit 100% O_2 durchgeführt. Bei dieser Anordnung genügt eine Dekompressionszeit von 35 min. Sie ist kürzer als nach 120 min Luftatmung bei 4,0 bar und Dekompression mit 100% O_2, was 45 min erfordert. Über die kritischen Halbwertszeiten am Ende der Dekompression orientieren die Abb. 2–6. Diese Versuche beweisen die Brauchbarkeit des Konzeptes, für *jedes* Kompartiment bzw. Gewebe mit gegebener Perfusion einen mit He im Vergleich zu N_2 2,65mal schnelleren Druckausgleich zu berechnen.

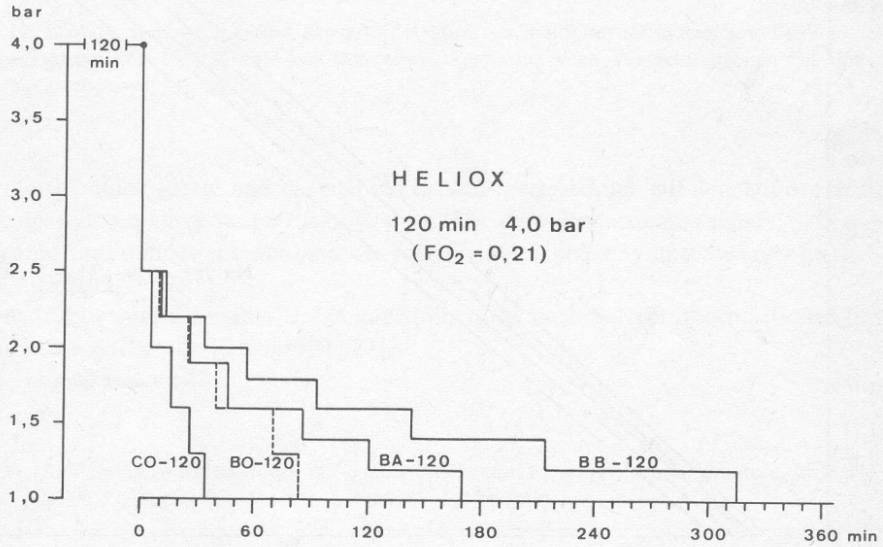

Abb. 10. Exposition mit 21% O_2 und 78% He während 120 min bei 4,0 bar. Entsprechend den Atemgasen während der Dekompression ergeben sich sehr unterschiedliche Dekompressionsprofile und -zeiten. Die erste Dekompressionsstufe liegt bei allen Dekompressionen bei 2,5 bar (CO-120 usw. s. Tabelle 6 und Abb. 2–5)

The Profile BB-120:
[4], p. 35, enlarged:

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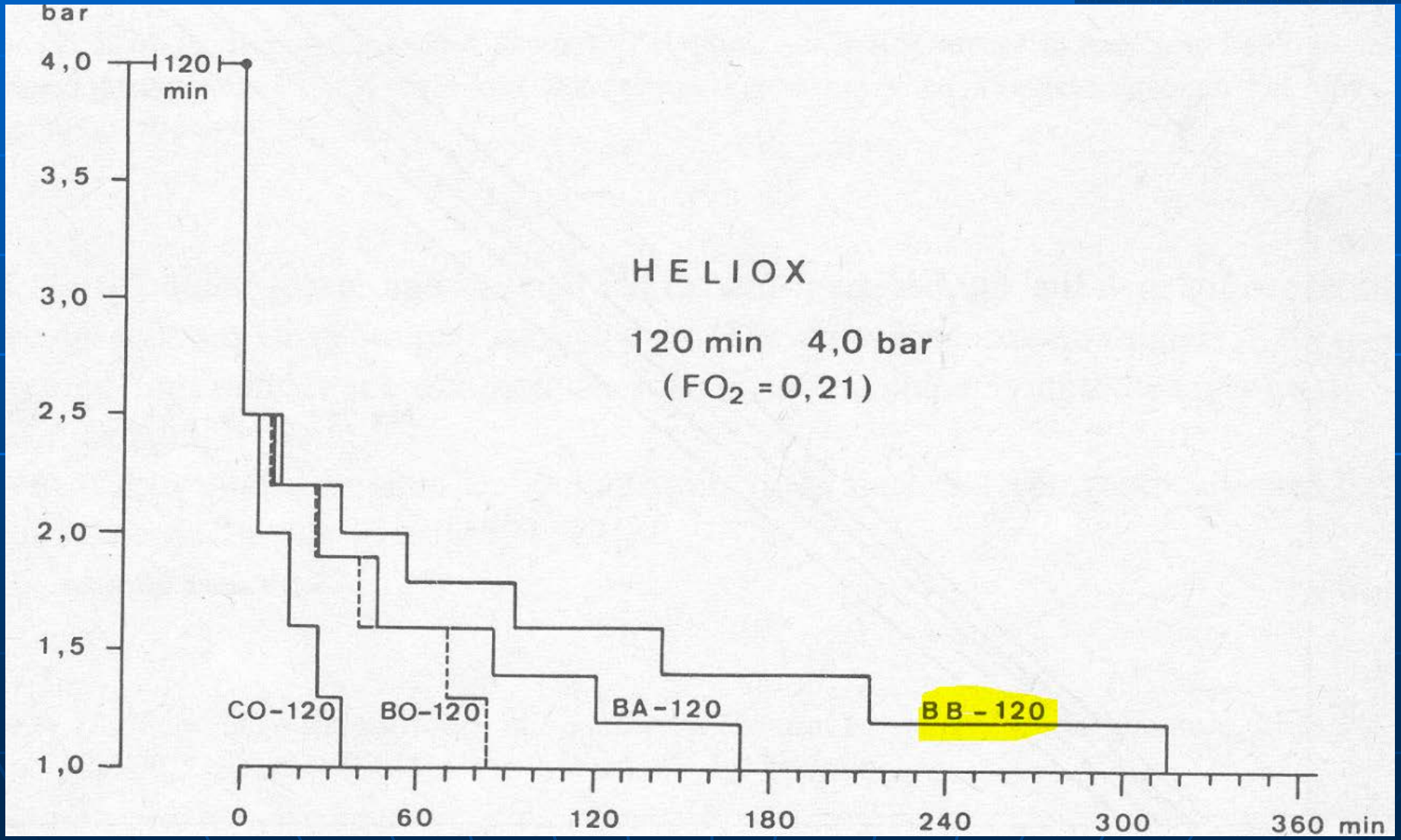
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)



The Profile:
→ [4], p. 20, Table 7

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ZH-L_{12}:
Validation of an old (1982)
experimental Heliox jump dive
(30m, 120 min)

BB-120	A	316	2,5	0/20		He 150–240
	B	232	2,5	3/8	Gelenke	

Dive series *BB-120* (bottom gas = decompression gas = Heliox21/78)
A: *TTS 316 min*, deepest stage *15 m* (*),
0 cases of DCS, 20 man-dives;

B: TTS 232 min, 3 cases of DCS in 8 man-dives

TTS = time-to-surface,
i.e.: sum of all stop times + (bottom depth / ascent rate)

(*) which is not completely
in-line with the profile from p.35, where the y-axis (pressure in [Bar])
does not really match properly to best-practice.

The Profile:
→ [4], p. 35:

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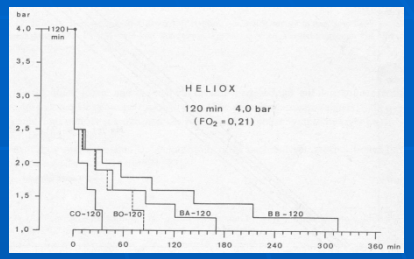

Dive series *BB-120 A* , TTS 316 min, there a graphical manual analysis of the plotted profile would yield ca.:

Stage [m]	decompression-run-time [min]	stop time [min]
15	0 – 12	12
12	12 – 33	21
10	33 – 57	24
7,5	57 – 92	35
6	92 – 142	50
4	142 – 203	61
2	203 – 316	113
TTS:		**316 min**

DIVE Version3 output:

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ZH-L_{12}:
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

```
 Deko Prognose:
15m Stopp Prognose Dekozeit:     12.0  Komp.#:  8
12m Stopp Prognose Dekozeit:     24.0  Komp.#: 10
 9m Stopp Prognose Dekozeit:     38.0  Komp.#: 11
 6m Stopp Prognose Dekozeit:     80.0  Komp.#: 13
 3m Stopp Prognose Dekozeit:    159.0  Komp.#: 16
TTS =    316.0
```

Result for BB-120 A:

The **1st. stage with 15 m, the stop time of 12 min AND the TTS aligns perfectly with [4]** , but the rest of the stop times per stage are redistributed due to the somewhat non-standard deco depths.

(*) TTS = time-to-surface,
i.e.: sum of all stop times + (bottom depth / ascent rate)

The Profile:
→ [4], p. 20, Table 7

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ZH-L_{12}:
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

BO-120	A	83	2,5	0/12		He 115–173
	B	65	2,5	3/8	Gelenke	

Dive series *BO-120* (bottom gas = Heliox21/78)
(decompression gas = 100 %O_2)
A: *TTS 83 min*, deepest stage *15 m,*
0 cases of DCS, 12 man-dives;

B: TTS 65 min, 3 cases of DCS in 8 man-dives

TTS = time-to-surface,
i.e.: sum of all stop times + (bottom depth / ascent rate)

The Profile:
→ [4], p. 35:

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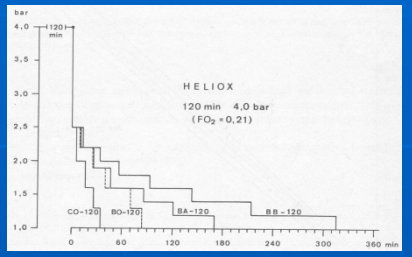

Dive series *BO-120 A* , TTS 83 min, there a graphical manual analysis of the plotted profile would yield ca.:

Stage [m]	decompression-run-time [min]	stop time [min]	
15	0 – 10	10	(2 * 5)
12	10 – 25	15	(3 * 5)
9	25 – 40	15	(3 * 5)
6	40 – 70	30	(6 * 5)
3	70 – 83	13	

TTS: **83 min**

DIVE Version3 output:

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ZH-L_{12}:
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

```
 Deko Prognose:
15m Stopp Prognose Dekozeit:     4.0  Komp.#:  8
12m Stopp Prognose Dekozeit:     8.0  Komp.#:  9
 9m Stopp Prognose Dekozeit:    13.0  Komp.#: 10
 6m Stopp Prognose Dekozeit:    18.0  Komp.#: 12
 3m Stopp Prognose Dekozeit:    39.0  Komp.#: 13
TTS =      83.0
```

Result for BO-120 A:

The **1st. stage with 15 m, the # of stages AND the TTS of 83 min aligns perfectly with [4];** but the *modulo 5 structure resembles very much the old DRÄGER tables and does not have a physiologic background,* but it reveals clearly „*excecutive editing*“ of the profile in order to gain insight into the half-times and tolerated overpressures of some compartments, pls. cf. the rightmost entries on Tab. 7 !

(*) TTS = time-to-surface, i.e.: sum of all stop times + (bottom depth / ascent rate)

https://www.divetable.info/manuals_4_free/70_komplett.pdf

back up material:

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ZH-L_{12}:
Validation of an old (1982) experimental Heliox jump dive (30m, 120 min)

Next question (subliminal): Could we make a serious PoC for DIVE Version 3_09?

DIVE V 3_09 (https://www.divetable.info/DIVE_V3/index.htm) and the manual are in german (https://www.divetable.info/DIVE_V3/DOXV3_0.pdf

The release train for the english version (V3_04) is somewhat slower … https://www.divetable.info/DIVE_V3/V3e/index.htm

Handling of DIVE:

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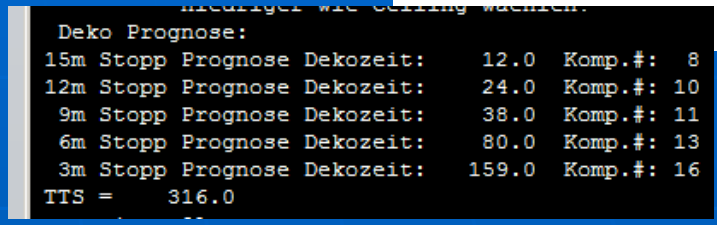

Input via keyboard fro **BB-120 A**:

„m“, „.21“, „.78“
(adaption of the breathing mix Heliox21 with 1% N_2 contamination)

„nc“, „8“
(loading the 1983 ZH-L_{12} N_2 Matrix)

„hc“, „2“
(loading the 1983 ZH-L_{12} Helium Matrix)

„d“, „30.“, „120.“
(d like „dive“, the above dive to 30 m & 120 min)

„a“
(a like „ascent“ yields the output of the deco prognosis)

Handling of DIVE:

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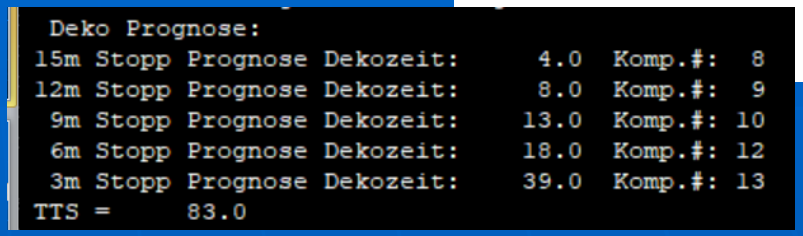
Input via keyboard fro **BO-120 A**:



„m“, „.21“, „.78“

„nc“, „8“

„hc“, „2“

„d“, „30.“, „120.“

„a“, „15.“
(ascent to the first stop @ 15 m)

„m“, „1.0“, „0.“, „0.“ → **„a“** (yields prognosis)
(decompression gas 100 % O_2)

Handling of DIVE:

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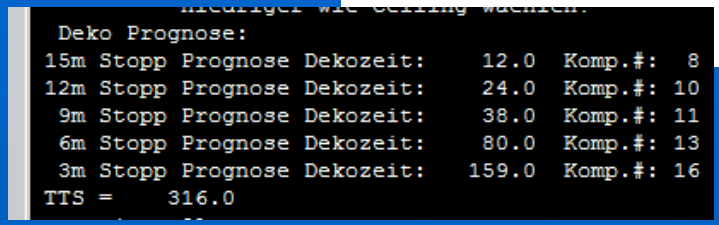

Fine tuning could be done via the commands:

→ ascent rate („**AR**“)

→ ambient atmospheric pressure at start („**L**“)

→ the respiratory coefficient („**R**“)

→ the ambient (water)-temperature („**te**“)

→ the water density („**di**“)

And with:

„**a**“

we recieve the complete decompression prognosis;
i.e.: the stop times per stage from 15 to 3 m
and the responsible leading compartment.

The latest DIVE Version for beta testing is always staged there:

https://www.divetable.info/beta/index.htm

along with information on date, size, features and the checksums
for verifying the download.

Synopsis: PoC of DIVE!

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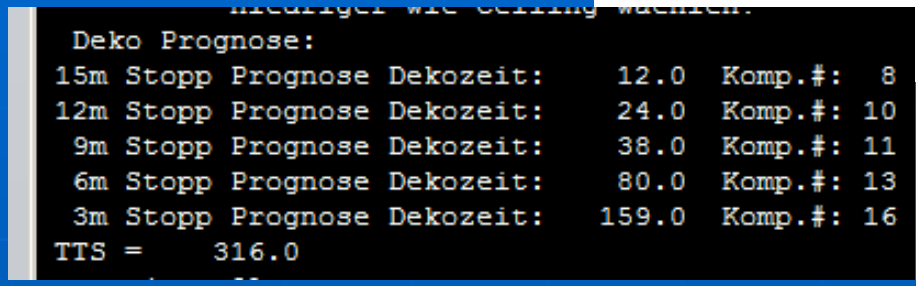

A **PoC** is a **proof of concept**, here confirmed for the DIVE decompression suite Version 3_09 *AND* the ZH-L_{12} system from 1983. Even if the methods match perfectly, this does not imply that both are correct or that the methods could be extrapolated to longer / deeper dives! It could just reveal that, for e.g., *we in this club did make the same errors!* Or different errors which yield by accident the same outcome!

The deco profile itself is not taken for granted, just because of the # of uneventful dives, here for BB-120 A it was only n = 20, but:

n > = 185 (sic!) is needed for a serious statistical analysis with a high selectivity, that is: **Power >= 0,85**.

Synopsis: PoC of DIVE!

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```
 Deko Prognose:
15m Stopp Prognose Dekozeit:    12.0  Komp.#:  8
12m Stopp Prognose Dekozeit:    24.0  Komp.#: 10
 9m Stopp Prognose Dekozeit:    38.0  Komp.#: 11
 6m Stopp Prognose Dekozeit:    80.0  Komp.#: 13
 3m Stopp Prognose Dekozeit:   159.0  Komp.#: 16
TTS =    316.0
```

A **dive contractor** would have handled the dive completely different (please cf. the last 3 slides at the end of this presentation)!

Especially due to the **workload and water temperature** and the often missing immersion: most of these experimental Zuerich dives have been done without substantial workload in a (warm) deco chamber!

In [4], on p. 20 & 21 we find:
„28 to 30° C“ and „10 min per 1h with 80 Watt“.

Synopsis: PoC of DIVE!

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```
 Deko Prognose:
15m Stopp Prognose Dekozeit:    12.0  Komp.#:  8
12m Stopp Prognose Dekozeit:    24.0  Komp.#: 10
 9m Stopp Prognose Dekozeit:    38.0  Komp.#: 11
 6m Stopp Prognose Dekozeit:    80.0  Komp.#: 13
 3m Stopp Prognose Dekozeit:   159.0  Komp.#: 16
TTS =    316.0
```

However, a detailed analysis of [4], p. 22 & 23, the „Abb. 4 & 5“ reveals:

→ the used compartments with half-times of:
→ Helium: 173 & 205 [min]
→ N_2: 458 & 542 [min]
→ do not match the published coefficients matrix on p. 27, instead:
→ by a sudden there are appearing 2 „new“ compartments:
→ i.e.: 173 / 458 min „between“ compartments # 14 & 15
→ and: 205 / 542 min „between“ compartments # 15 & 16
→ the indicated FN_2 und thus the
→ calculated inertgas overpressures ($p_{i.g.t}$) <u>can not be substantiated!</u>

Synopsis: PoC of DIVE!

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```
 Deko Prognose:
15m Stopp Prognose Dekozeit:     4.0  Komp.#:  8
12m Stopp Prognose Dekozeit:     8.0  Komp.#:  9
 9m Stopp Prognose Dekozeit:    13.0  Komp.#: 10
 6m Stopp Prognose Dekozeit:    18.0  Komp.#: 12
 3m Stopp Prognose Dekozeit:    39.0  Komp.#: 13
TTS =      83.0
```

And, interestingly enough, the

→ **DCIEM Diving Manual (1992) (*)** table yields no comparable profile, Heliox starts @ 36 m , bottom time max: 100 min, TTS = 152 min

→ **NDTT 5. ed. (2019) (*)** no heliox at all

(*)

→ DCIEM: Defence and Civil Institute of Environmental Medicine, the manual could be downloaded for free there:
https://www.divetable.info/manuals_4_free/p125936.pdf

→ NDTT: Norwegian Diving- and Treatment Tables, the manual could be downloaded for free there:
https://www.divetable.info/manuals_4_free/219.pdf

Synopsis: PoC of DIVE!

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```
 Deko Prognose:
15m Stopp Prognose Dekozeit:      4.0   Komp.#:  8
12m Stopp Prognose Dekozeit:      8.0   Komp.#:  9
 9m Stopp Prognose Dekozeit:     13.0   Komp.#: 10
 6m Stopp Prognose Dekozeit:     18.0   Komp.#: 12
 3m Stopp Prognose Dekozeit:     39.0   Komp.#: 13
TTS =      83.0
```

BUT:
→ the new **USN** table
(REVISION 7, CHANGE A 30 APRIL 2018)
yields a TTS = 104 min (p. 12-32):

Table 12-4. *Surface-Supplied Helium-Oxygen Decompression Table (Continued).*
(DESCENT RATE 75 FPM—ASCENT RATE 30 FPM)

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	Decompression Stops (fsw) — Stop times (min) include travel time, except first HeO_2 and first O_2 stop																Chamber O_2 Periods
			190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	
			BOTTOM MIX										50% O_2						100% O_2		
100	10	3:20																		0	0
	15	3:20																		0	0
	20	2:00																10	11	17	1
	30	2:00																10	15	24	2
Max O_2=*32.3%* Min O_2=*14.0%*	40	2:00																10	18	32	2
	60	2:00																10	25	44	3
	80	2:00																10	28	52	3
	100	2:00																10	31	56	3
	120	2:00																10	32	58	3

Synopsis: PoC of DIVE!

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```
 Deko Prognose:
15m Stopp Prognose Dekozeit:      4.0   Komp.#:  8
12m Stopp Prognose Dekozeit:      8.0   Komp.#:  9
 9m Stopp Prognose Dekozeit:     13.0   Komp.#: 10
 6m Stopp Prognose Dekozeit:     18.0   Komp.#: 12
 3m Stopp Prognose Dekozeit:     39.0   Komp.#: 13
TTS =      83.0
```

AND:

→ the **MNT 92, Version 2012** yields a TTS = 117 min:

Profondeur : 30 mètres — **Héliox 20-22 % oxygène**

Temps au fond		100 min	110 min.	120 min	130 min					
Remontée au palier		2	2	2	2					
Heliox 20-22 %	15 m	5	5	10	10					
	12 m	15	15	20	20					
	9 m	20	25	25	30					
Oxygène	6 m	50	55	60	65					
Total décomp.		1 h 32	1 h 42	1 h 57	2 h 07					