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Is the „DGUV Vorschrift 40“ adequate for underwater-“work“?

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Is the
„DGUV Vorschrift 40“
adequate for
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(*) DGUV Vorschrift 40
reads
Deutsche Gesetzliche Unfallversicherung

in english:
German legal regulations for the prevention of industrial accidents, rule # 40:
diving operations

As per January 2012

(previously this was the:
BGV C23 from 1.10.1979

the „BG“ here means:
Workmen‘s Compensation Board)

Link to download:
https://publikationen.dguv.de/regelwerk/dguv-vorschriften/1089/taucherarbeiten?c=13

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Abstract:

The DGUV 40 is challenged with a certain paradigm of one box profile to check whether this regulation is adequate for underwater work, i.e.:
physical workload. According to other approved methods this seems to be not the case. Thus the recommendation is not to use the DGUV 40 for strenous dives or only with additional safety measures like „padding“.

Method:

With 3 very simple, but very different methods which take physical workload into account we compare the original decompression schedule without workload for the box profile 15 m / 240 min. These methods are:

1) Bühlmann et al. ([204], p. 348 – 365)
2) Workman/Bornmann ([204], p. 307 – 330),and as well:
3) Doolette et al. (ASM 2010, Session A6)

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Discussion:

The methods (1) Bühlmann and (3) Doolette with ca. 1 L/min O_2 consumption, as well „padding“ with only the next time step yield similar, comparable schedules (charts # 11 & 12).

But the DGUV #40 deviates already with 11 min from the unmodified ZH-86 (pls. cf. chart # 10), thus it is more probable than not, that this table does not take any physical workload into account which would exceed the one used for calculation of the ZH-86 (pls. cf. chart # 6).

Result:

For strenous dives, i.e. underwater activities with a certain physical workload the DGUV #40 should not be used as such. Instead it should be used only with additional safety measures like „padding“ or with a significant increased pO_2 during the decompression phase.

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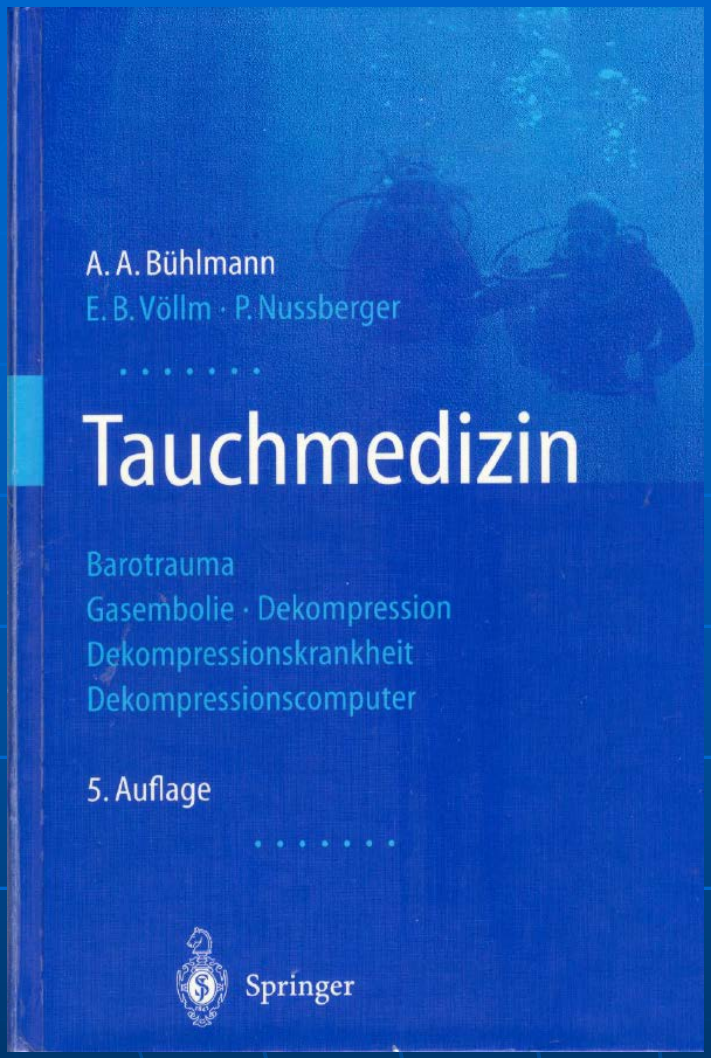
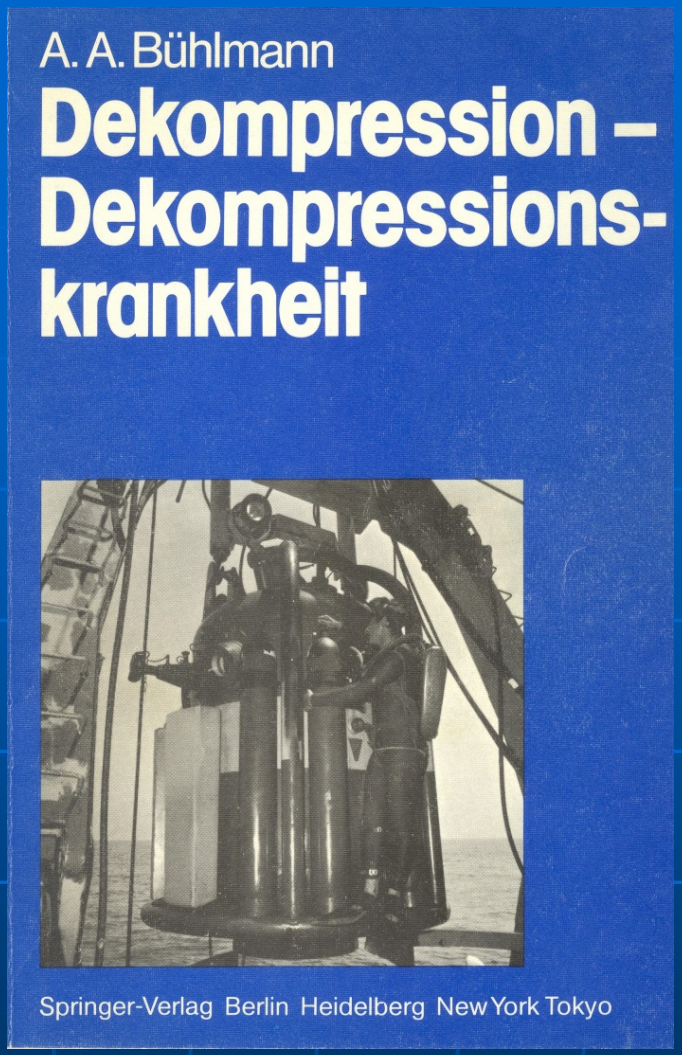
Used tables:

→ ZH-86: Luftdekompressionstabelle
(air decompression table for
0 to 700 m above sea level)
(Zürich 1986) 0 – 700 m ü. NN
(with coefficients according ZH-L 16 B from
Albert Alois Bühlmann et al. [65])

→ [4] Bühlmann, A.A. (1983): Dekompression - Dekompressionskrankheit, Springer, ISBN: 3-540-12514-0

→ Unfallverhütungsvorschrift Taucherarbeiten
DGUV Vorschrift 40
(bisher BGV C23 vom 1.10.1979) mit der Durchführungsanweisung vom Januar 2012
Attachment 1, Table 2: Drucklufttabelle (air diving table), p. 47 - 53





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[65], table # 32 on p. 225 – 228

Citation concerning workload from [4], p.20: „28 to 30° C“ and „10 min per 1h with 80 Watt“.

Unfallverhütungsvorschrift Taucherarbeiten DGUV Vorschrift 40

(bisher BGV C23)

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Tauch-zeit (min)	Aufstieg bis zur ersten Austauch-stufe (min:sec)	Haltezeiten während des Austauchens auf den Austauchstufen (min)						Gesamtzeit der Dekom-pression (min:sec)
		18 m	15 m	12 m	9 m	6 m	3 m	
Tauchtiefe 42 m								
7	3:30	–	–	–	–	–	–	3:30
10	3:15	–	–	–	–	–	3	6:15
15	3:00	–	–	–	–	3	5	11:00
20	3:00	–	–	–	–	3	12	18:00
25	2:45	–	–	–	3	7	17	29:45
30	2:45	–	–	–	5	10	25	42:45
35	2:30	–	–	3	7	15	30	57:30
40	2:30	–	–	3	10	20	35	70:30
45	2:30	–	–	5	12	25	40	84:30
50	2:30	–	–	5	15	25	45	92:30
60	2:15	–	3	10	17	30	60	122:15
70	2:15	–	5	12	25	40	75	159:15

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Further References:

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Is the
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→ [204] Bennett, Peter B., Elliott, David H.(eds.) (1975) The Physiology and Medicine of Diving and Compressed Air Work, Second Edition, Bailliere Tindall, London ISBN: 0-7020-0538-X

→ NEDU Report 1942-02, p. 26

→ Doolette DJ, Gerth WA, Gault KA. Probabilistic Decompression Models With Work-Induced Changes In Compartment Gas Kinetic Time Constants. Navy Experimental Diving Unit, Panama City, FL, USA; in: UHMS Annual Scientific Meeting, St. Pete Beach, Florida, June 3-5, 2010, Session A6

→ And, as well:
36th. UHMS workshop p. 103

→ 37th. UHMS workshop, p. 145

Short overview of the methods to take the physical workload into account:

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1) Method Bühlmann et al., from: [204], p. 348 – 365
The TTS of the decompression schedule without workload is multiplied with a factor depending on bottom time and bottom depth of the original box profile (1.18 → 1.20 → 1.44).

2) Method USN / Workman / Bornmann, from: [204], p. 307 – 330
„virtual bottom time“: the real bottom time is multiplied with a factor depending on the kind of inert gas: 1.5 for N_2 and 2.0 for Helium.

3) Method NEDU / Doolette, from ASM 2010, Session A6
The perfusion rates and thus the half times of certain compartments of a perfusion model are modified according to the increased oxygen consumption due to an increased workload (this is implemented in DIVE 3_09, pls. cf. chart #14).

4) Method „pedestrians approach“
„padding“: planning with next depth / next time steps instead of the real used values.

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15 m / 240 min

original decompression schedule, without workload
(pls. cf. as well the german version:
DOI: 10.13140/RG.2.2.28277.40169)

→ ZH-86 / TTS = 72
2 / 69

→ DIVE / TTS = 73
3 / 69

→ DGUV / TTS = 61
60

→ DCIEM / TTS = 70

```
 Deko Prognose:
 6m Stopp Prognose Dekozeit:      3.0  Komp.#:  8
 3m Stopp Prognose Dekozeit:     69.0  Komp.#: 10
TTS =      73.0
```

15 m / 240 min;
decompression schedule *with physical workload*:

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1) ZH-86, Method A.A. Bühlmann; increased TTS:
2 * 1.4 / 69 * 1.4 → TTS = 95

2) Method USN; virtual bottom time: 240 * 1.5 = 360
DIVE / TTS = 155
22 / 132

```
 Deko Prognose:
 6m Stopp Prognose Dekozeit:    22.0  Komp.#:  9
 3m Stopp Prognose Dekozeit:   132.0  Komp.#: 12
TTS =    155.0
```

3) Method Doolette;
DIVE with O_2 consumption:

1.0 L / min; TTS = 96
12 / 83

```
 Deko Prognose:
 6m Stopp Prognose Dekozeit:    12.0  Komp.#:  9
 3m Stopp Prognose Dekozeit:    83.0  Komp.#: 12
TTS =     96.0
```

1.5 L / min; TTS = 110
17 / 92

```
 Deko Prognose:
 6m Stopp Prognose Dekozeit:    17.0  Komp.#:  9
 3m Stopp Prognose Dekozeit:    92.0  Komp.#: 13
TTS =    110.0
```

2.0 L / min; TTS = 124
21 / 102

```
 Deko Prognose:
 6m Stopp Prognose Dekozeit:    21.0  Komp.#: 10
 3m Stopp Prognose Dekozeit:   102.0  Komp.#: 13
TTS =    124.0
```

15 m / 240 min;
decompression schedule *with physical workload*:

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4) „padding“ with:
next depth: 18 m
next time: 270 min

→ ZH-86: table exceeded
→ DGUV: table exceeded

Simulation with DIVE 15 m / 270 min:
TTS = 91

```
 Deko Prognose:
 6m Stopp Prognose Dekozeit:     9.0  Komp.#:  8
 3m Stopp Prognose Dekozeit:    81.0  Komp.#: 10
TTS =      91.0
```

Simulation with DIVE 18 m / 240 min:
TTS = 136

```
 Deko Prognose:
 6m Stopp Prognose Dekozeit:    34.0  Komp.#:  8
 3m Stopp Prognose Dekozeit:   100.0  Komp.#: 11
TTS =     136.0
```

Simulation with DIVE 18 m / 270 min:
TTS = 166

```
 Deko Prognose:
 6m Stopp Prognose Dekozeit:    44.0  Komp.#:  9
 3m Stopp Prognose Dekozeit:   120.0  Komp.#: 12
TTS =     166.0
```

Bonus Material: Source for DIVE Version 3_09

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Download free of charge:

→ DIVE V 3_09
(https://www.divetable.info/DIVE_V3/index.htm)

→ and the german manual
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

Implementation of Method NEDU / Doolette in DIVE:

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via the command / mnemonic: workload („**W**“)
then input of the O_2 consumption from 0.25 → 4.0 L/min
and one scaling factor WF from 0.5 → 4.0:
→

```
 was jetzt?w
Eingabe Sauerstoffverbrauch [ L / min ]  0.25 -> 4.0 L/min: 1.25
 Eingabe Skalierungsfaktor WF [./.]  0.5 -> 4.0 0.75
 was jetzt?
```

With these 2 parameters the Doolette formula runs in the background for certain compartments:

$$HWZ_{work}=HWZ_{rest}/(1+WF(VO2_{work}-VO2_{rest}))$$

Fine tuning of DIVE:

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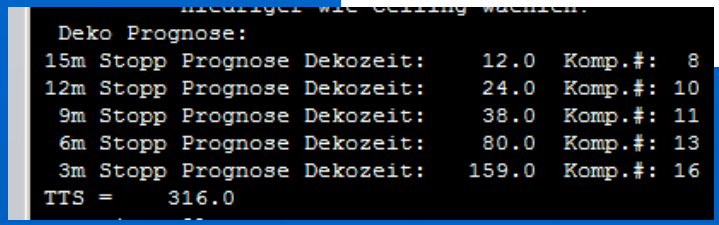

Fine tuning could be done via the commands:

→ ascent rate („**AR**“)

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

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

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

→ the water density („**di**“)

→ Buehlmann Safety Factor („**B**“)

And with:

„**a**“

we recieve the complete decompression prognosis;
i.e.: the stop times in min per stage, modulo 3 m
and the responsible leading compartment & the rounded up TTS in min.
The latest DIVE Version for beta testing is always staged there:

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

along with information on production date, size in bytes, new features and the checksums for verifying the download.