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# The mapping of a french air diving table (MT92) to a standard Haldane- / Workman- / Schreiner - algorithm

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# Abstract:

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The published french air diving tables MT92 ([1] & [2]) could be mapped via a simple algebraic transformation directly to a standard decompression algorithm based on blood perfusion with a linear relationship between calculated compartment inert gas overpressures and the ambient pressure.

With this mapping the MT92 table entries could be calculated with any desktop decompression software and thus compared to other published air diving tables like DCIEM, USN & NDTT [5].

As well the MT92 framework could be extended to other than printed:
→ or greater bottom depths
→ or longer bottom times
→ higher $pO_2$ during decompression
→ modified decompression stages

if operational requirements need an adaption of the published tables.

# Methods (1):

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All standard perfusion models (Haldane, Workman, Schreiner, …) offer the following generic linear relationship between a tolerated inertgas over-pressure in a theoretical (tissue-) compartment and the ambient, absolute pressure at diving depth:

$$P_{t.tol.}ig = P_{amb} / b + a \qquad (1)$$

| Variable | Definition |
|---|---|
| $P_{t.tol.}ig$ | tolerated inert gas pressure, for each compartment, [Bar], sum of all partial pressures of the present inert gases |
| a | boundary value at a theoretical ambient pressure of 0 Bar, i.e. the axis intercept [Bar] |
| $P_{amb}$ | ambient pressure, absolute pressure of the breathing mix [Bar] |
| b | 1/b pressure gradient: value of increase per pressure unit depth (dimensionless), i.e. the slope of the straight line |

# Methods (2):

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The published parameters for the MNT92 ([1], [2], and [4] and all the references therein) are:

$$P_{crit} = < ( 1 + A / T_{1/2} ) * (P_{ambient} + B) \qquad (2)$$

with the following compartment half-times:

$T_{1/2}$ = 5, 7, 10, 15, 20, 30, 40, 50, 60, (75), 80, 100, 120 [min]

and with:

A = 8.0 [min]
B = 0.4 [Bar]
ascent speed = 17 m/min

# Methods (3):

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If we now identify $P_{crit}$ with $P_{tissue,\ tolerated}$, i.e. if we equate eq. (1) with eq. (2) we get the following mapping

$$P_{crit} = P_{t.tol.ig} \quad \Rightarrow$$

$$( 1 + A / T_{1/2} ) * (P_{ambient} + B) = P_{amb} / b + a \quad \Rightarrow$$

$$( 1 + A / T_{1/2} ) * P_{ambient} + ( 1 + A / T_{1/2} ) * B \quad \Rightarrow$$

$$\mathbf{1 / b = ( 1 + A / T_{1/2} )} \quad \text{AND}$$
$$\mathbf{a = ( 1 + A / T_{1/2} ) * B} \qquad (3)$$

# Methods (4):

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With the already published compartment parameters from: [4], p. 90 & p. 91, there results the following coefficient matrix, useable for standard desktop decompression software with the following identification from equation (3):

A MT92 = a
B MT92 = b

MT92.TXT - Editor

Datei Bearbeiten Format Ansicht ?

| # | TAU | A MT92 | B MT92 |
|---|---|---|---|
| 01 | 5.00 | 1.0400 | 0.3846 |
| 02 | 7.00 | 0.8570 | 0.4667 |
| 03 | 10.00 | 0.7200 | 0.5556 |
| 04 | 15.00 | 0.6133 | 0.6521 |
| 05 | 20.00 | 0.5600 | 0.7142 |
| 06 | 30.00 | 0.5066 | 0.7894 |
| 07 | 40.00 | 0.4800 | 0.8333 |
| 08 | 50.00 | 0.4640 | 0.8627 |
| 09 | 60.00 | 0.4533 | 0.8823 |
| 10 | 75.00 | 0.4426 | 0.9036 |
| 11 | 80.00 | 0.4400 | 0.9090 |
| 12 | 100.00 | 0.4320 | 0.9259 |
| 13 | 120.00 | 0.4266 | 0.9375 |

For evaluation readily available for download:
https://www.divetable.info/beta/MT92.TXT

# Et voilà ! Results (0):

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Comparison between the MT92 published table entries and calculations via DIVE [3] in 5 paradigms:

| Paradigm # | MT92 | DIVE V3 | Error |
|---|---|---|---|
| | TTS [min] (*) | TTS [min] (*) | circa ΔTTS [%] |
| 1) 12 m / 360 min | **40:45** | **40** | < 1.85 |
| 2) 33 m / 100 min | **151:45** | **151** | < 0.5 |
| 3) 42 m / 25 min | **29:45** | **30** | < 0.9 |
| 4) 42 m / 70 min | **159:15** | **159** | < 0.2 |
| 5) 60 m / 35 min | **121:30** | **122** | < 0.5 |

(pls. cf. slides # 8 – 11 for details)
(*) TTS = time-to-surface, i.e.:
sum of all stop times + (bottom depth / ascent speed)

# Et voilà ! Results (1):

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#1) 12 m, 360 min:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 360 | 0:45 | - | - | - | - | - | 40 | 40:45 |

```
 Deko Prognose:
 3m Stopp Prognose Dekozeit:     40.0  Komp.#: 16
TTS =     40.0
 was jetzt?z
Luftdruck:  1.030 AMV: 25.0 RQ:  1.000 O2:   0.210 He:   0.000 N2:   0.790
 CNS:     0.0 OTU:     0.0 AR =  17.00 VO2 =  0.25 Latency: N   K_A =   1.0
 NUM FLAG: OFF   Wassertemp.:   20.00  Wasserdichte:  998.203   PRT=  41.5
Korrektur: Y GFHI=   1.00 GFLO=   1.00 LAST STOP=  3.0 m First Stop =  3.0 m
Tiefe:  12.00    Zeit:    360.0 max. Tiefe=  12.00 ges. Tauchzeit=    360.0
  berechnete Kompartimentwerte mit N2 Matrix: MN92      He Matrix: ZH-L
```

#3) 42 m, 25 min:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 25 | 2:45 | - | - | - | 3 | 7 | 17 | 29:45 |

D3_09 - [Graphic1]

```
 Deko Prognose:
 9m Stopp Prognose Dekozeit:     1.0  Komp.#:  4
 6m Stopp Prognose Dekozeit:     8.0  Komp.#:  5
 3m Stopp Prognose Dekozeit:    17.0  Komp.#:  7
TTS =     30.0
 was jetzt?z
Luftdruck:  1.013 AMV: 25.0 RQ:  1.000 O2:   0.210 He:   0.000 N2:   0.790
 CNS:    10.4 OTU:    28.1 AR =   9.00 VO2 =  0.25 Latency: N   K_A =   1.0
 NUM FLAG: OFF   Wassertemp.:   20.00  Wasserdichte:  998.203   PRT=  25.6
Korrektur: Y GFHI=   1.00 GFLO=   1.00 LAST STOP=  3.0 m First Stop =  9.0 m
Tiefe:  42.00    Zeit:     25.0 max. Tiefe=  42.00 ges. Tauchzeit=     25.0
  berechnete Kompartimentwerte mit N2 Matrix: MN92      He Matrix: ZH-L
```

# Et voilà ! Results (2):

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#2) 33 m, 100 min:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 100 | 1:45 | - | - | 10 | 25 | 40 | 75 | 151:45 |

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D3_09 - [Graphic1]

```
 Deko Prognose:
12m Stopp Prognose Dekozeit:    13.0  Komp.#:  7
 9m Stopp Prognose Dekozeit:    23.0  Komp.#:  9
 6m Stopp Prognose Dekozeit:    40.0  Komp.#: 11
 3m Stopp Prognose Dekozeit:    71.0  Komp.#: 16
TTS =    151.0
 was jetzt?z
Luftdruck:  1.000 AMV: 25.0 RQ:  1.000 O2:   0.210 He:   0.000 N2:   0.790
 CNS:    27.8 OTU:    81.6 AR =   7.00 VO2 =  0.25 Latency: N   K_A =   5.0
 NUM FLAG: OFF   Wassertemp.:   20.00  Wasserdichte:  998.203   PRT=  42.4
Korrektur: Y GFHI=   1.00 GFLO=   1.00 LAST STOP=  3.0 m First Stop = 12.0 m
Tiefe:  33.00    Zeit:    100.0 max. Tiefe=  33.00 ges. Tauchzeit=    100.0
  berechnete Kompartimentwerte mit N2 Matrix: MN92      He Matrix: ZH-L
 Nr.:  1 3.4564 P N2 0.0000 P HE Sum.=  3.4564 Ceil. m=  0.00 Putol:  0.929
```

# Et voilà ! Results (3):

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#4) 42 m, 70 min:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 70 | 2:15 | - | 5 | 12 | 25 | 40 | 75 | 159:15 |

D3_09 - [Graphic1]

```
 Deko Prognose:
15m Stopp Prognose Dekozeit:      8.0  Komp.#:  6
12m Stopp Prognose Dekozeit:     14.0  Komp.#:  7
 9m Stopp Prognose Dekozeit:     23.0  Komp.#:  9
 6m Stopp Prognose Dekozeit:     39.0  Komp.#: 11
 3m Stopp Prognose Dekozeit:     69.0  Komp.#: 16
TTS =    159.0
 was jetzt?z
Luftdruck:  0.990 AMV: 25.0 RQ:  1.000 O2:   0.210 He:   0.000 N2:   0.790
 CNS:    29.2 OTU:    78.7 AR =   7.00 VO2 =  0.25 Latency: N   K_A =   8.0
 NUM FLAG: OFF   Wassertemp.:   20.00  Wasserdichte:  998.203   PRT=  42.9
Korrektur: Y GFHI=   1.00 GFLO=   1.00 LAST STOP=  3.0 m First Stop = 15.0 m
Tiefe:  42.00    Zeit:     70.0 max. Tiefe=  42.00 ges. Tauchzeit=     70.0
  berechnete Kompartimentwerte mit N2 Matrix: MN92      He Matrix: ZH-L
```

# Et voilà ! Results (4):

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#5) 60 m, 35 min:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 35 | 3:30 | 3 | 5 | 10 | 15 | 30 | 55 | 121:30 |

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# Discussion (1):

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The agreement between the published/printed MT92 table entries and the software-derived values is nearly perfect! The small deviations in the TTS and the stop times per stage stem from:

→ Our usage of one compartment with half-time of 75 min (not used in MT92 but in older french tables)

→ since fractions of minutes are unpracticable/unrealistic in a run-time / dive plan, DIVE rounds automatically to the nearest next INTEGER minute

→ and, not properly defined parameters within MT92 framework:
- → respiratory coefficient
- → water temperature & density
- → ambient air pressure @ start / end of decompression
- → executive editing (proprietary to MT92)

However: these delta times in the TTS are all marginal and the related error is by far smaller than the errors introduced by the usual devices for operational diving like depth gauges & -monitors or $O_2$ analyzers.

# Discussion (2):

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The comparison with other air diving tables ([5]) reveals as well that a higher physical workload i.e. higher $O_2$ consumption is only marginally adressed within the MT92 framework.

This could be even more so confirmed if compared to the ZH-86 system ([6]), where the respiratory coefficient $R_q = 1$, and no allowance is made for increased $VO_2$ , thus the physical workload is neglected ([7]).

*If used under such circumstances, an increased $pO_2$ during decompression or padding (usage of increased depth and / or bottom times for operational dive planning than actually dived) is strongly encouraged.*

# Sources / References (1):

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[1] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000000690963/
accessed: 12.02.2021

[2] https://sneti.eu/wp-content/uploads/2020/06/5-Annexes-Arr%C3%AAt%C3%A9-Mention-A-2019-TABLES-dae_20190524_0003_0001.pdf
accessed: 12.02.2021

[3] the SubMarineConsulting Group (1991) DIVE: a decompression suite; pls. cf. slide #16

[4] Julien HUGON: Vers une modélisation biophysique de la décompression, T H È S E, 22 Novembre 2010

[5] Manuals for free:
https://www.divetable.info/manuals_4_free/index.htm

# Sources / References (2):

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

[7] Salm, Albi (2021) Is the DGUV40 adequate for underwater-"work"? DOI: 10.13140/RG.2.2.10079.28324

# 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 …
***DIVE V 3_09 is not compatible with all older versions!***

https://www.divetable.info/DIVE_V3/V3e/index.htm

# Handling of DIVE:

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The paradigm dives from above via these commands,
the input of commands and parameters are in the quotes: „ “

→ „**d**“ (simulation of a dive profile with these parameters:)
→ „**60.**“ (bottom depth)
→ „**35.**“ (bottom time)
→ „**a**“ (ascent)

→ the manipulation of the coefficients matrices is done via:
→ „**nc**“ (nitrogen coefficients):

with the option 12 the matrix from
slide #6 could be loaded
into the service engine of the
DIVE software.

```
 was jetzt?nc
Eingabe der N2-Koeffizienten Matrix:
 1 = Buehlmann ZH-L 16C Computer,
 2 = Dr. Max Hahn,
 3 = File: N2COEFF.TXT,
 4 = U.S. Navy 1965,
 5 = USN: VVAL18,
 6 = USN: VVAL76-1,
 7 = Buehlmann ZH-L 16B Tabelle,
 8 = Buehlmann ZH-L 12 (1983),
 9 = M. Hahn DECO-BRAIN P2-2, (1985),
10 = File: F10.TXT,
11 = File: F11.TXT,
12 = MT92. ?
```

# 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**“)

→ last stop depth („**LS**“)

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.