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On the reliability of dive computer generated run-times 07.02.2022, Part V

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DOI:

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Abstract:

Idea: as per part I, DOI: 10.13140/RG.2.2.16260.65929
and per part II, DOI: 10.13140/RG.2.2.11343.41126
and per part III, DOI: 10.13140/RG.2.2.21973.50405
and per part IV, check of a DCIEM implementation, to be published asap!

Here, in *Part V*, we checked the ZH-L16C implementation of one SHEARWATER® dive computer with the original source, the air diving table ZH-86 from A. A. Bühlmann [2] along selected table entries as well with a freeware/shareware implementation [1], [3] as a 2nd. benchmark.

Conclusion: the manufacturers claims on using the ZH-L16C model could be verified: within the limited precision of dive computers / depth gauges / dive watches there is reasonable agreement for operational air-diving in the recreational domain.
Methods: slides # 3 → 5
Results: slides # 6 → 14
Discussion, Conclusion & Recommendations: slides # 15 & 16
References: slides # 17 → 21

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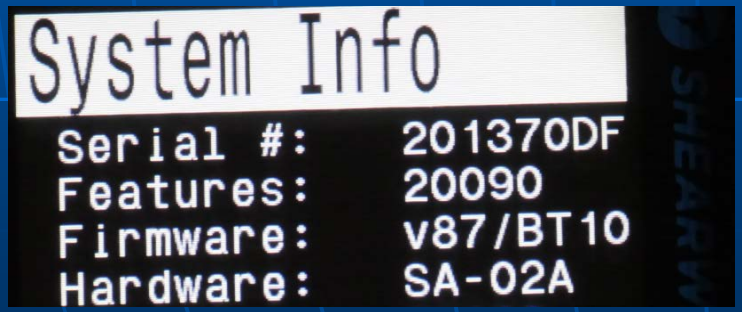
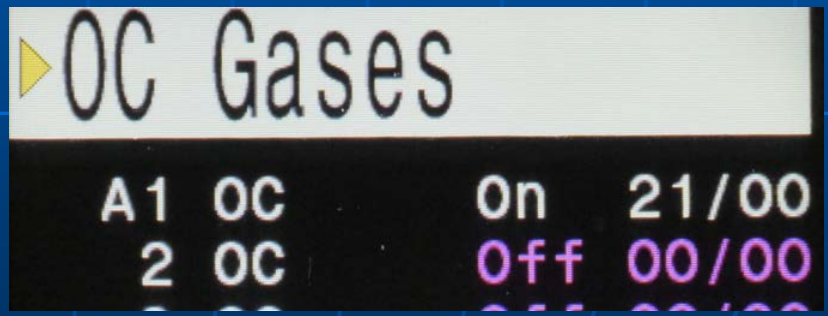
Methods (1):

Comparison of the run-times/TTS from the original ZH-86 air table ([1], slides # 17 → 19) with the calculated run-times by DIVE ([1] & [3]) and the dive-computer generated run-times, obtained in (surface-)planning mode set to „air“, pls. cf. slides # 6 → 14.

The tested dive computer is the SHEARWATER PERDIX ® with the latest firmware V87 from 2021-11-01, put to air in „OC Tec“ mode:





The tools to simulate the dive schedules are the so-called „DECO PLANNER“ and the „NDL Planner“. The possible entries in the „DECO PLANNER“ are: for bottom depth 3 → 150 m, and bottom time 5 → 180 min; the „NDL Planner“ runs from 12 → 45 m.

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Methods (2):

The ZH-86 entries are taken from the book [2] & slides # 17→ 19, DIVE Version 3_11 are screen copies, the upper part showing unmodified values, i.e. GF = 1.0, the lower part with the GF. The required configurations to adapt for the settings in the PERDIX are on slide # 20. The Shearwater „OC Deco Planner“ values are digital stills. „OC“ here stands for „Open Circuit“, which is normally used in air diving (in contrast to „CC“, closed circuit, a rebreathing device).

Tables Ia & Ib (slide # 6 & 7) compare the various NDL in minutes from 9 → 48 m bottom depth. The NDL is a „no-decompression-limit“, aka „no-stop-limit“ for a diver to surface from a dive without decompression stops.

The slides in the results-section (slides # 6 – 14) show the schedules with bottom depth, bottom time and the stop times for the 3, 6, 9, 12, … m stops, each with a clip from DIVE 3_11 and a digital still from the dive computer.

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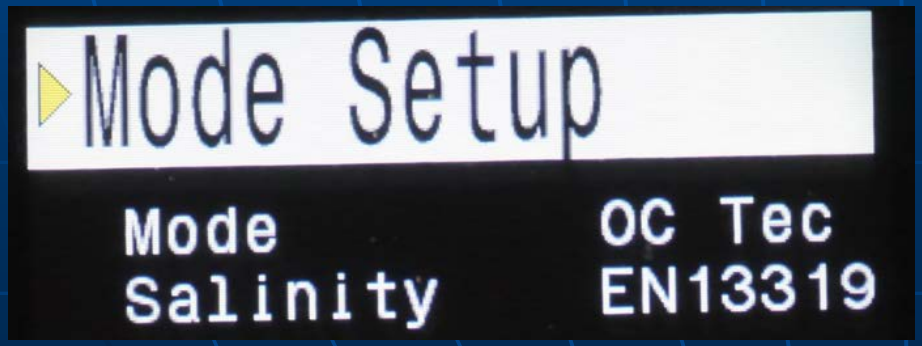
Methods (3):

The dive computer is set to „OC Tec“ mode which allows for configuration of the gradient factors GF: these have been set to GF High = GF Low = 0.99 to allow for, at least a limited, comparability with the original ZH-86 values from the printed air diving tables (GF Hi = GF Lo = 1.00 or 100 %). The comparability is limited because the ZH-86 tables are calculated with the ZH-L16B set, whereas the dive computer is set to use the ZH-L16C values. As per [2], p. 157, the –B set is for table calculations whereas the –C set should be used for dive computers. Thus the ZH-86 tables could serve as a benchmark with nearly similar TTS / stop times per stage in comparison to any dive computers calculations using the –C set.



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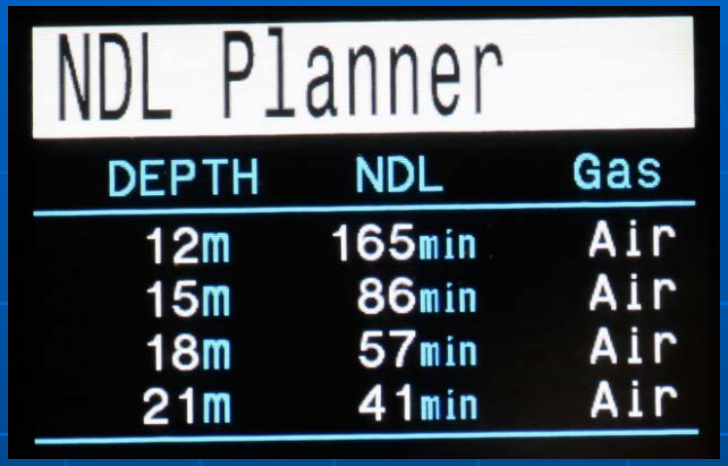
Results (1):

Table Ia: comparison of the NDL, the „no-decompression limits“:

depth [m]	NDL [min] ZH-L16C with GF Hi = GF Lo = 0.99	NDL [min] PERDIX
9	720	-
12	**175**	**165**
15	**86**	**86**
18	**57**	**57**
21	**39**	**41**
24	**29**	**31**
27	**22**	**23**
30	**16**	**19**
33	**13**	**15**



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Results (2):

Table Ib: comparison of the NDL, the „no-decompression limits“:

depth [m]	NDL [min] ZH-L16C with GF Hi = GF Lo = 0.99	NDL [min] PERDIX
36	**11**	**13**
39	**9**	**12**
42	**8**	**10**
45	**7**	**9**
48	5	**-**

N.B.: the “OC Deco Planner” is not accessible in “AIR” mode, but the “NDL Planner” is.

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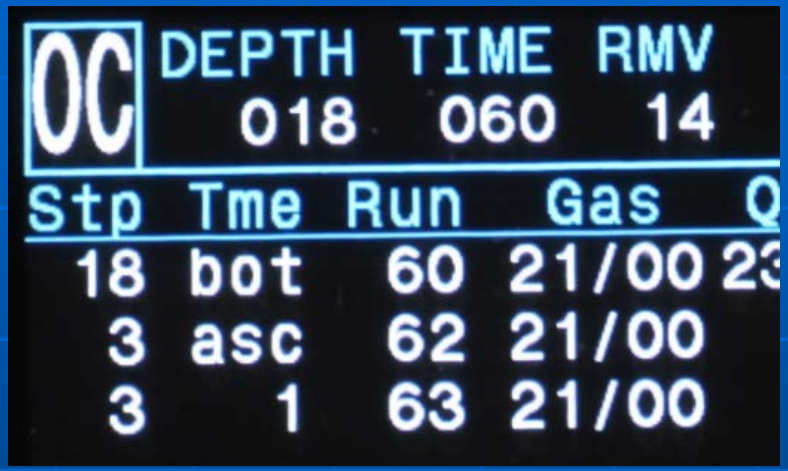
Results (3):

comparison of the schedule: 18 m, 60 min bottom time:




```
 deco prognosis:
   3m stop  prognosis deco time:      1.0  comp.#:  5
TTS =      3.0
 deco prognosis with gradient factors:   GF HI=   0.99 GF LO=   0.99
 3m stop  prognosis deco time:      1.0  GF =   0.99  comp.#:  5
TTS =      4.0
```

Rem.: the „TTS“ , the „time-to-surface“ is defined as:
sum of all stop times **+ (**bottom depth **/** ascent speed**);**
run, run time = bottom time **+** TTS

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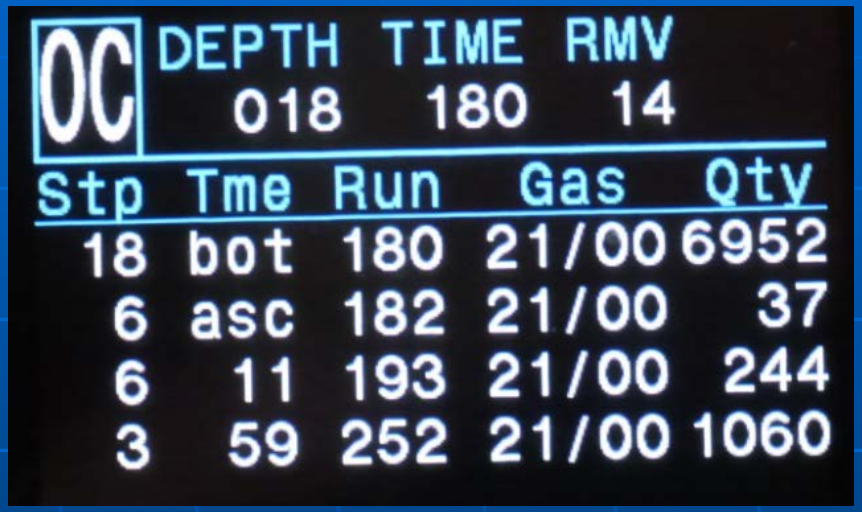
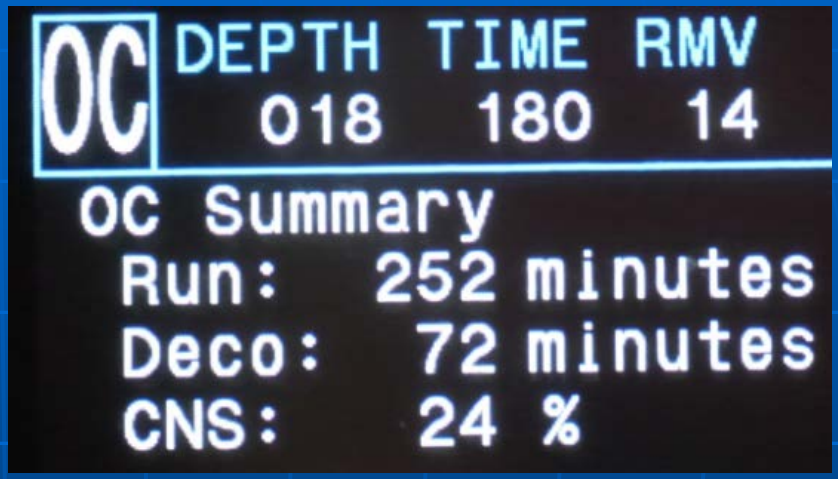
Results (4):

comparison of the schedule: 18 m, 180 min bottom time:






```
 deco prognosis:
   6m stop  prognosis deco time:      9.0  comp.#:  7
   3m stop  prognosis deco time:     58.0  comp.#:  9
TTS =      68.0
 deco prognosis with gradient factors:   GF HI=   0.99 GF LO=   0.99
 6m stop  prognosis deco time:     10.0  GF =   0.99  comp.#:  7
 3m stop  prognosis deco time:     59.0  GF =   0.99  comp.#:  9
TTS =      71.0
```

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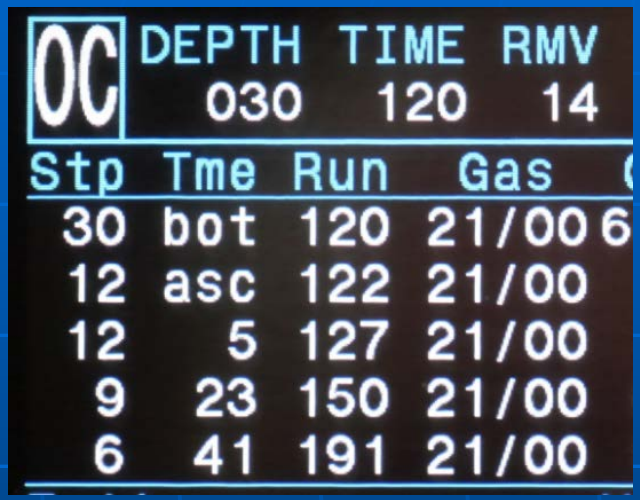
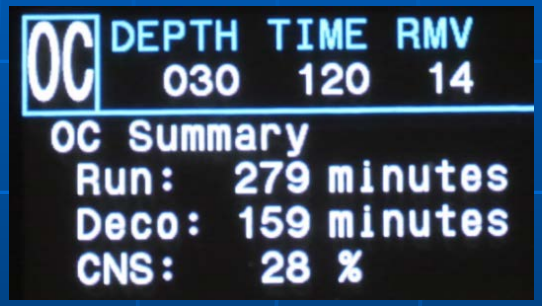
Results (5):

comparison of the schedule: 30 m, 120 min bottom time:






```
 deco prognosis:
  12m stop  prognosis deco time:      5.0  comp.#:  6
   9m stop  prognosis deco time:     23.0  comp.#:  7
   6m stop  prognosis deco time:     41.0  comp.#:  8
   3m stop  prognosis deco time:     86.0  comp.#: 10
TTS =    158.0
 deco prognosis with gradient factors:   GF HI=   0.99 GF LO=   0.99
12m stop  prognosis deco time:      5.0  GF =   0.99  comp.#:  6
 9m stop  prognosis deco time:     23.0  GF =   0.99  comp.#:  7
 6m stop  prognosis deco time:     41.0  GF =   0.99  comp.#:  8
 3m stop  prognosis deco time:     87.0  GF =   0.99  comp.#: 10
TTS =    160.0
```

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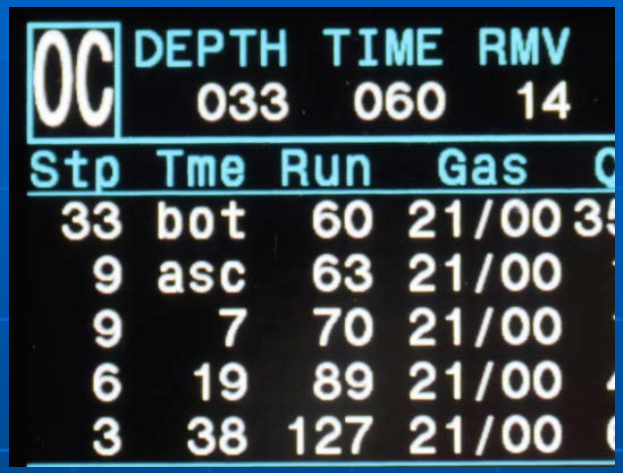
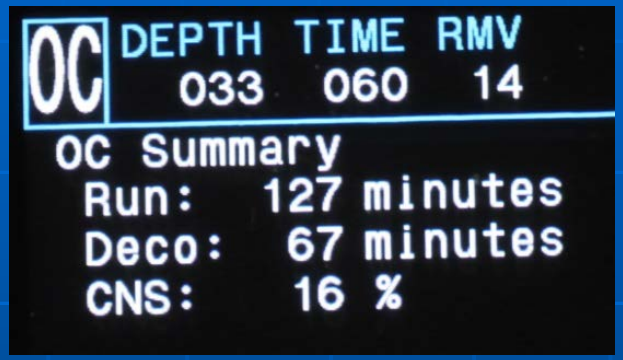
Results (6):

comparison of the schedule: 33 m, 60 min bottom time:






```
 deco prognosis:
   9m stop  prognosis deco time:       7.0  comp.#:  5
   6m stop  prognosis deco time:      18.0  comp.#:  6
   3m stop  prognosis deco time:      38.0  comp.#:  8
TTS =      66.0
 deco prognosis with gradient factors:   GF HI=   0.99 GF LO=   0.99
 9m stop  prognosis deco time:       7.0  GF =   0.99  comp.#:  5
 6m stop  prognosis deco time:      18.0  GF =   0.99  comp.#:  6
 3m stop  prognosis deco time:      38.0  GF =   0.99  comp.#:  8
TTS =      67.0
```

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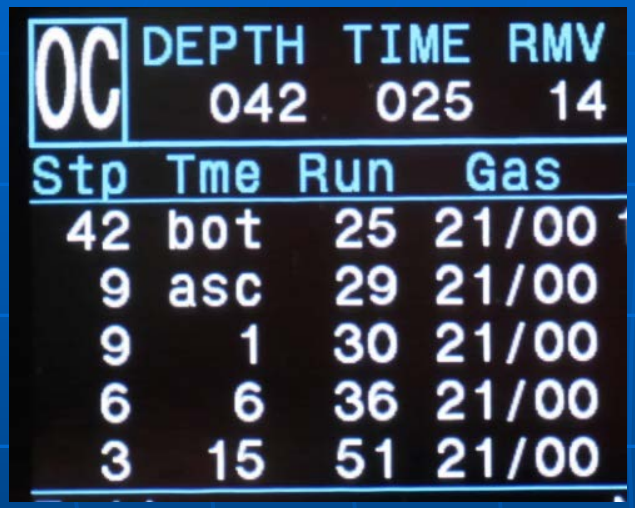
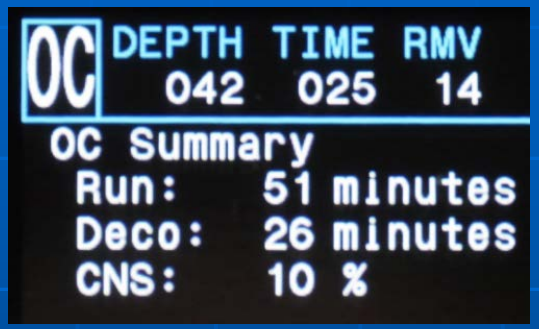
Results (7):

comparison of the schedule: 42 m, 25 min bottom time:






```
 deco prognosis:
   9m stop  prognosis deco time:      2.0  comp.#:  3
   6m stop  prognosis deco time:      6.0  comp.#:  4
   3m stop  prognosis deco time:     15.0  comp.#:  6
TTS =     27.0
 deco prognosis with gradient factors:   GF HI=   0.99 GF LO=   0.99
 9m stop  prognosis deco time:      2.0  GF =   0.99  comp.#:  3
 6m stop  prognosis deco time:      6.0  GF =   0.99  comp.#:  4
 3m stop  prognosis deco time:     15.0  GF =   0.99  comp.#:  6
TTS =     28.0
```

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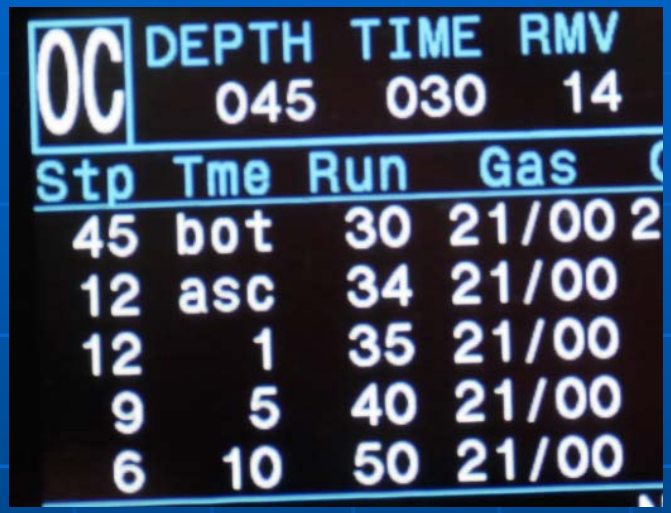
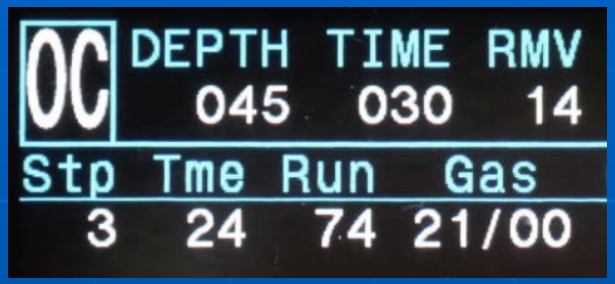
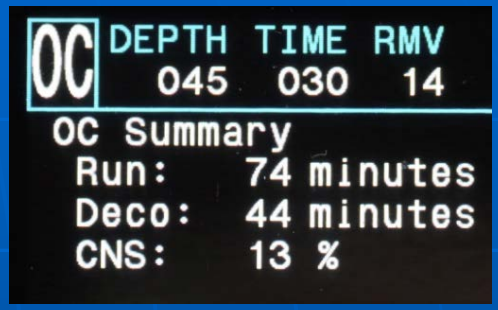
Results (8):

comparison of the schedule: 45 m, 30 min bottom time:








```
 deco prognosis:
  12m stop  prognosis deco time:      2.0  comp.#:  3
   9m stop  prognosis deco time:      5.0  comp.#:  4
   6m stop  prognosis deco time:     10.0  comp.#:  5
   3m stop  prognosis deco time:     24.0  comp.#:  7
TTS =     45.0
 deco prognosis with gradient factors:   GF HI=   0.99 GF LO=   0.99
12m stop  prognosis deco time:      1.0  GF =   0.99  comp.#:  3
 9m stop  prognosis deco time:      5.0  GF =   0.99  comp.#:  4
 6m stop  prognosis deco time:     10.0  GF =   0.99  comp.#:  5
 3m stop  prognosis deco time:     24.0  GF =   0.99  comp.#:  7
TTS =     45.0
```

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Results (9):

comparison of the schedule: 51 m, 30 min bottom time:

OC	DEPTH	TIME	RMV
	051	030	14

Stp	Tme	Run	Gas	Qty
51	bot	30	21/00	2425
12	asc	34	21/00	223
12	4	38	21/00	121
9	7	45	21/00	183
6	15	60	21/00	330

OC	DEPTH	TIME	RMV
	051	030	14

Stp	Tme	Run	Gas
3	30	90	21/00

```
 deco prognosis:
  15m stop  prognosis deco time:      1.0  comp.#:  3
  12m stop  prognosis deco time:      4.0  comp.#:  4
   9m stop  prognosis deco time:      7.0  comp.#:  4
   6m stop  prognosis deco time:     15.0  comp.#:  6
   3m stop  prognosis deco time:     29.0  comp.#:  7
TTS =     61.0
 deco prognosis with gradient factors:   GF HI=   0.99 GF LO=   0.99
15m stop  prognosis deco time:      1.0  GF =   0.99  comp.#:  3
12m stop  prognosis deco time:      4.0  GF =   0.99  comp.#:  4
 9m stop  prognosis deco time:      7.0  GF =   0.99  comp.#:  4
 6m stop  prognosis deco time:     15.0  GF =   0.99  comp.#:  6
 3m stop  prognosis deco time:     30.0  GF =   0.99  comp.#:  7
TTS =     63.0
```

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Discussion:

Tables Ia & Ib show a good agreement between the calculated ZH-86 table NDL and the dive computer generated values.

The other schedules agree as well. The delta-times of 1 min +/- 0.5 are well within the precision of used equipment for practical diving.
Thus these deviations are negligible for recreational air-diving and do not imply any safety/security hazards.

Conclusion:

That is, the manufacturers claims of using the ZH-L16C set with the GFs = 0.99 could be fully verified. This means as well, that considerations concerning the risk of recreational air diving put forth by Bühlmann ([2], pp. 158 & 164 - 178) are valid here for the tested dive computer with these air-diving configurations as well.

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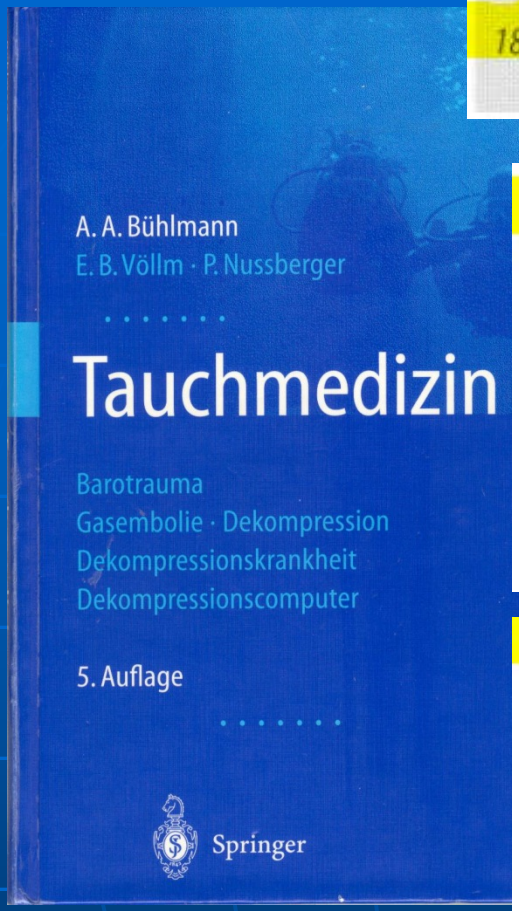
Recommendations:

As per Part I, **DOI: 10.13140/RG.2.2.16260.65929** and / or
part II: **DOI: 10.13140/RG.2.2.11343.41126** , and / or
part III, **DOI: 10.13140/RG.2.2.21973.50405** .

To achieve a transparency for the customer (the diver) and a fair comparability between dive computers, *Dive Computer Manufacturers* should:

→ reveal the used set of constants (i.e. those constants used at run-time!)
→ as well, like in any other desktop decompression-software:
→ the used water temperature & density, ascent rates, respiratory coefficient, ambient air pressure, transit times, etc. etc. … and:
→ implement quality assurance procedures
→ esp. after software/firmware update / patches
→ agree on a set of benchmarks, standardized for all players in the market
→ and / or a code-review, with the results to be published



18	47	2		1	3
	60	2		5	7

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33	14	3			1	4
	20	3			4	7
	25	3		2	7	12
	30	3		4	11	18
	35	3		6	17	26
	40	2	2	8	23	35
	45	2	4	11	28	45
	50	2	5	15	31	53
	60	2	9	19	37	67

51	9	4				4	8
	12	4			3	6	13
	15	4		2	4	8	18
	18	4		4	5	13	26
	21	3	3	4	7	18	35
	24	3	4	5	9	24	45
	27	3	2	3	6	13	28	55
	30	3	3	4	8	16	32	66

Comparison with ZH-86 table:

Source: [65], pp. 227; i.e.: http://www.divetable.eu/BOOKS/65.pdf; the yellow display is ours: "Tauchmedizin", Albert A. Bühlmann, Ernst B. Völlm (Mitarbeiter), P. Nussberger; 5. Auflage in 2002, Springer, ISBN 3-540-42979-4

18					
47	2			1	3
60	2			5	7
70	2			11	13
80	2			18	20
90	2			21	23
105	2			27	29
120	2		2	35	39
150	2		9	45	56
180	2		15	63	80
210	2		21	85	108

30					
17	3			1	4
25	3			5	8
30	2		2	7	11
35	2		3	14	19
40	2		5	17	24
45	2		9	23	34
50	2	1	10	28	41
60	2	3	13	35	53
75	2	10	22	43	77
90	2	16	28	56	102
105	2	5 19	39	73	138
120	2	8 24	41	92	167

Comparison with ZH-86 table:

Source: [65], pp. 227; i.e.: http://www.divetable.eu/BOOKS/65.pdf; the yellow display is ours: "Tauchmedizin", Albert A. Bühlmann, Ernst B. Völlm (Mitarbeiter), P. Nussberger; 5. Auflage in 2002, Springer, ISBN 3-540-42979-4

42	9	3				1	4	D
	12	3				4	7	D
	15	3			1	5	9	E
	18	3			4	6	13	F
	21	3		2	4	10	19	F
	24	3		3	6	16	28	G
	27	3		4	7	19	33	G
	30	3	2	4	9	24	42	G
	33	3	2	6	10	26	47	G
	36	3	3	7	13	28	54	H
45	9	4				2	6	E
	12	4				5	9	E
	15	4			3	5	12	E
	18	3		2	4	9	18	F
	21	3		3	5	13	24	G
	24	3		4	6	18	31	G
	27	3	2	4	9	22	40	G
	30	3	3	6	10	27	49	H

Comparison with ZH-86 table:

Source: [65], pp. 227; i.e.: http://www.divetable.eu/BOOKS/65.pdf;
the yellow display is ours: "Tauchmedizin",
Albert A. Bühlmann, Ernst B. Völlm (Mitarbeiter), P. Nussberger;
5. Auflage in 2002, Springer, ISBN 3-540-42979-4

Additional Settings required for DIVE V 3_11 to reflect the special ZH-L16C calculations within the „OC Deco Planner“ (slides # 6 → 14 and [3])**:**

Source: https://www.divetable.info/beta/D3_11.exe

→ **„NC“:** selection of the ZH-L16C set („1“, = default)
→ **„AR“:** ascent rate: 10 m / min
→ **„DI“:** for water density 1020.00 kg/m^3
→ **„L“:** for ambient pressure at start of dive
→ fraction of oxygen **fO_2,** respiratory quotient **R_q & water temperature are set to the software defaults**

To simulate the „**OC Tec**“ settings in the Shearwater PERDIX ®:
→ **„GF“: for Gradient Factors** High = Low = 0.99
→ used bottom times for planning: - 0.5 or - 1.0 min to accomodate for the computers descent rate of 18 m / min; since **DIVE** uses, as <u>usual in table calculations, per default an instantaneous descent.</u>

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References:

[1] Vered N., Rosenblat M., Salm, A. (2021) Synopsis & Fact Sheet DIVE Version 3_11,
DOI: https://dx.doi.org/10.13140/RG.2.2.17024.56326

[2] → **[65]** Albert A. Bühlmann, Ernst B. Völlm (Mitarbeiter), P. Nussberger (5. Auflage in 2002) Tauchmedizin, Springer, ISBN 3-540-42979-4

[3] Rosenblat M., Vered N., Eisenstein Y.; Salm A. (2022) Recovery of selected ZH-86 air-diving schedules via a decompression shareware
DOI: 10.13140/RG.2.2.34235.13609

The dive computer manufacturers homepage:
https://www.shearwater.com/