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Theoretical Benchmark for the „Twenty-first century surface-supplied Heliox decompression tables“ 22.01.2024

Miri Rosenblat, TAU
Nurit Vered, Technion Haifa
Albi Salm, SubMarineConsulting

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Contents:

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Abstract (1):

The DCIEM Heliox diving tables [2] are wide-spread in professional use [1] and considered conservative due to a low rate of DCS ([1] & [2] and all the references therein).

Their counterpart tables from the United States Navy (USN), the so-called surface-supplied Heliox (He-O_2) tables have had a long history: the first version from Momsen et al. appeared in 1939 with heavy field-tests along the epic rescue & salvage efforts for the U.S.S. SS-192, the submarine „SQUALUS“ [3]. The latest empirical changes resulted in Revision 4, Change A (1-March-2001) and have been tested successfully with ca. 140 dives on the USS MONITOR ([12] for SAT dives, but all the other references therein).

However, in the topical, more than 5 years-effort and 232 skilfully designed and successfully completed man-dives, NEDU revised these USN surface-supplied Heliox tables again and proposed a candidate replacement table, the:

„Twenty-First Century Surface-Supplied Heliox Decompression Table”.

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Abstract (2):

This table was designed with a statistical probability of contracting a decompression sickness [P(DCS)] of less than ca. 2.3 % ([4], [5], [6] and all the references therein).

We selected three Heliox diving schedules as primary, first dives on the day, and compared the new „Twenty-first century surface-supplied Heliox decompresson tables“ from USN / NEDU (ss He-O_2), which have been designated as the “final candidate replacement” [4], pp. B-2, where operationally possible, with the DCIEM tables.

Thereafter we tried to map these schedules on a seasoned perfusion model (ZH-L16) and recompute them with and without a pair of simple gradient factors [8].

The benchmarked parameters have been the TTS with and without air breaks and the K-values [9].

Methods (1):

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We selected only three profiles as our show cases:

Profile 1: 30 m / 120 min
Profile 2: 170 fswg / 60 min
Profile 3: 230 fswg / 40 min.

Profile 1 is the historical Heliox-jump dive of 1982, tested by Albert Alois Bühlmann with 12 man-dives and no cases of DCS [7].

The profiles 2 & 3 from the printed DCIEM tables [2] with a Heliox16/84 match the range of the allowed oxygen-contents in the candidate replacement ss-HeO_2 tables [4] & [5]. However, the decompression staging and the gas-mixes for the deepest and intermediate stops are different: for DCIEM it is Air, for NEDU it is the bottom-mix or/and EAN50.

As both tables / methods exploit 30 & 20 feet stops on oxygen, the K-value [9] is a benchmark parameter besides the raw TTS;
(the TTS = time-to-surface, defined as:
sum of all stop times **+** (bottom depth / ascent speed) [+ air breaks])

Methods (2):

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Conversion factors used from [6], p.3 as the user-interface of the DIVE framework [10] is metric-oriented (i.e.: SI units):

Table 1. Pressure Conversion Factors[a]

Factor	Standard[b]		USN, metric geometric		USN, metric pressure	
	Imperial	Metric	Imperial	Metric	Imperial	Metric
Seawater density (gm/cm^3)	1.02480	1.01972	1.02723	1.02723	1.02723	1.01972
fsw/atm	33.078		33.000[c]		33.000[c]	
msw/bar		10.000		9.9268		10.000[d]
msw/fsw	0.30632		0.3048		0.30704	

[a] Assumed values from which the other values follow in each convention are shaded.

[b] Undersea and Hyperbaric Medicine. North Palm Beach (FL): Undersea and Hyperbaric Medical Society. Vol. 20, No. 1, Mar 1993-. Pressure Conversion Table; [inside back cover].[11]

[c] U.S. Navy convention (e.g., U.S. Navy Diving Manual).[1,2,4]

[d] BRd 2806(2) U.K. Military Diving Manual. Fleet Publications and Graphics Organisation. April 2014 Edition. Air Diving, Chapter 6, Decompression, para 0603.g.[12]

Wayne A. Gerth, David J. Doolette
VVal-79 Thalmann Algorithm Metric and Imperial Air Decompression Tables
NEDU TR 16-05,

Methods (3):

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The DIVE framework [10] has been used two-fold for this benchmark:

➔ as a pure *number-cruncher*
to calculate the K-values (and others) by running the unmodified, printed schedules,
pls. cf. the log-files in the DATA section;

Table 1. Pressure Conversion Factors[a]

Factor	Standard[b]		USN, metric geometric		USN, metric pressure	
	Imperial	Metric	Imperial	Metric	Imperial	Metric
Seawater density (gm/cm^3)	1.02480	1.01972	1.02723	1.02723	1.02723	1.01972
fsw/atm	33.078		33.000[c]		33.000[c]	
msw/bar		10.000		9.9268		10.000[d]
msw/fsw	0.30632		0.3048		0.30704	

[a] Assumed values from which the other values follow in each convention are shaded.
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[c] U.S. Navy convention (e.g., U.S. Navy Diving Manual).[1,2,4]
[d] BRd 2806(2) U.K. Military Diving Manual. Fleet Publications and Graphics Organisation. April 2014 Edition. Air Diving, Chapter 6, Decompression, para 0603.g.[12]

➔ as a *benchmark partner* with a ZH-L16-type of perfusion model with or without gradient factors (GF).

The profile-simulations with DIVE have had used the following parameters:
- ➔ water density as per slide # 6
- ➔ ascent speed 9.3 m / min
- ➔ Bühlmann Safety Factor
- ➔ breathing gas mixes:
  - ➔ bottom mix Heliox 16/84
  - ➔ deepest & intermediate stops: Air
  - ➔ 9 & 6 m: „pure“ Oxygen.

Methods (4):

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As the unmodified ZH-L16C system for N_2, and, as well the ZH-L16A coefficients for Helium decompression, are usually lacking a certain conservativism in comparison to DCIEM and even the seasoned USN procedures [11], we used then throughout the following gradient factor system (GF):

➔ GF High = GF Low = 0.9

If a 1st. deep stop appeared 3 m deeper than the deepest stop without a GF, then this stop time was added to the stop-time, where the gas-switch from bottom mix to Air / EAN50 took place.

The change from bottom mix to air/EAN50 was simulated after the ascent to the deepest stop, the change from air to oxygen was simulated after the end of the 12 m stop.

Then the TTS for the 9 & 6 m stops has been calculated with $fO_2 = 0.9$, balance N_2, but the stops themselves have been simulated with $fO_2 = 1.0$ for the assessment of the K-values and to achieve a maximum comparability with the methods used for the 21st. century tables.

Results (1) for Profile 1:

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Table / Profile:	Deepest Stop	K-value [./.]	TTS [min]	Air Breaks	TDT [min]
BO-120A 30 m / 120 min	15 m	664,872	83 + 4	3 x	87 + 15
NEDU 90 fswg / 120 min Min. O2	90 fswg	465,454	112 + 3	4 x	115 + 20
NEDU 90 fswg / 120 min Max. O2	90 fswg	808,661	112 + 3	4 x	115 + 20

Results (2) for Profile 2:

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Table / Profile:	Deepest Stop	K-value [./.]	TTS [min]	Air Breaks	TDT [min]
DCIEM 170 ft / 60 min	90 fsw	850,069	143 + 4	3 x	161
NEDU 170 fswg / 60 min	90 fswg	846,609	157 + 6	5 x	163 + 25
DIVE 3_11 52.2 m / 60 min	(33) 30 m	332,068	158 + 5	5 x	163 + 25

Results (3) for Profile 3:

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Table / Profile:	Deepest Stop	K-value [./.]	TTS [min]	Air Breaks	TDT [min]
DCIEM 230 ft / 40 min (Heliox, Air, O_2)	120 fsw	977,993	152 + 5	3 x	170
NEDU 230 fswg / 40 min (Heliox, EAN50, O_2)	90 fswg	1,301,322	199 + 7	5 x	206 + 25
DIVE 3_11 **GF .9 / .9** 70.62 m / 40 min (Heliox, Air, O_2)	(42) 39 m	387,757	158 + 8	4 x	166 + 20
DIVE 3_11 **GF .8 / .8** 70.62 m / 40 min (Heliox, EAN50, O_2)	39 m	682,452	156 + 8	4 x	164 + 20

Discussion & Conclusion:

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The divergent philosophies / algorithms between the NEDU / USN, DCIEM and ZH-L16 are already described at great length elsewhere.

What stays here to ascertain are the relative similarities in the TTS despite the differences in staging and decompression-mixes and thus the K-values.

As well there is comforting serendipity that the run-times from the ZH-L16 C with a GF 0.9 resp. 0.8 do not vary by much, if we concede the inaccuracies of dive-computers/depth-gauges/oxygen-analyzers and the time-delays in following a run-time through communication with top-side!

So there is hope for a bright future of the new

"21st. century ss He-O_2" tables!!!

(*) הו-יה ים עמוק

(*) hebrew for:
Hoo-Yah Deep Sea

DATA (1a) profile 1, the Heliox 21/78, 30 m / 120 min:

from [7]; decompression with 100 % O_2:

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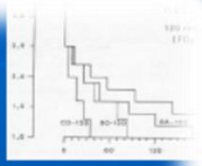
Dive series *BO-120 A* , TTS 83 min,
there a graphical manual analysis
of the plotted profile would yield ca.:



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**	

Bühlmann safety factor:
calculational depth = actual planned i.e.: tabulated depth * 1.03 +1 [m], thus:
(30 m – 1 m) / 1.03 = 28.16 ➔ 91.70 fsw, thus:
90 fswg / 120 min NEDU schedule, pls. cf. slide # 16

DATA (1b) Heliox 21/78; 30 m / 120 min:

from [7]; decompression with 100 % O_2 simulation to evaluate the K-values:

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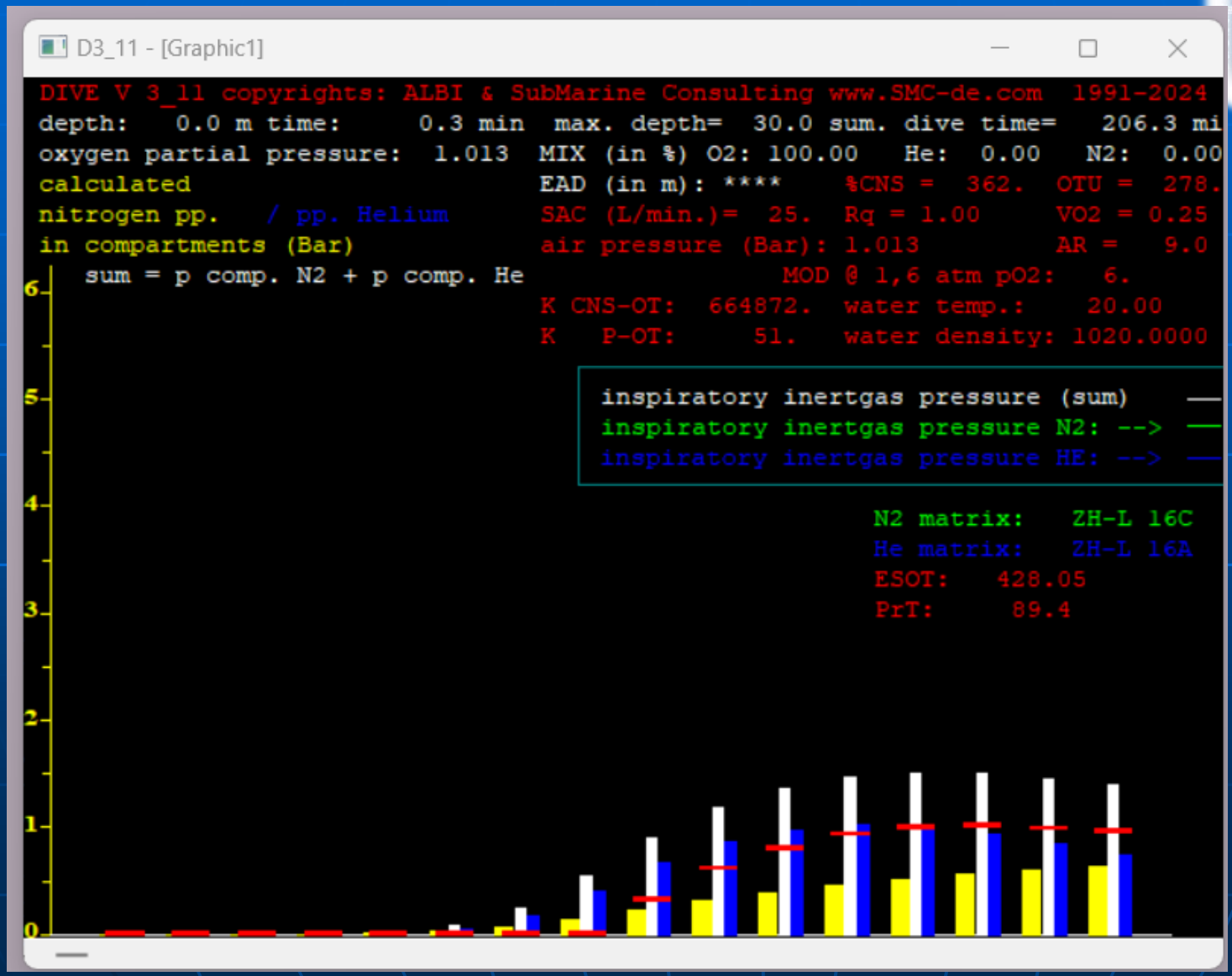

DATA (1c) Heliox 21/78; 30 m / 120 min:

from [7]; decompression with 100 % O_2 simulation to evaluate the K-values; corresponding log-file for control:

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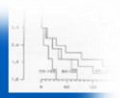

Dive series *BO-120 A*, TTS 83 min, there a graphical manual analysis of the plotted profile would yield ca.:

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	

Yr: 2024 Mon: 01 D: 17 Hr: 10 Min: 00 Version: 3_11 , 02/2024

BO - 120 A profile

	DEPTH	TIME	SUM.TIME	N	O	HE	CNS	OTU	K CNS	K POT	GAS
X	0.0	0.0	0.0	0.79	0.21	0.00	0.	0.	0.	0.	0.0
D	30.0	120.0	120.0	0.01	0.21	0.78	33.	88.	4119.	2.	12041.5
A	15.0	1.7	121.7	0.01	0.21	0.78	33.	88.	4142.	2.	104.7
D	15.0	10.0	131.7	0.00	1.00	0.00	133.	120.	80585.	7.	628.4
A	12.0	0.3	132.0	0.00	1.00	0.00	136.	121.	83304.	7.	23.4
D	12.0	15.0	147.0	0.00	1.00	0.00	236.	162.	252334.	17.	830.0
A	9.0	0.3	147.3	0.00	1.00	0.00	237.	163.	255250.	18.	25.9
D	9.0	15.0	162.3	0.00	1.00	0.00	287.	199.	403788.	28.	717.5
A	6.0	0.3	162.7	0.00	1.00	0.00	287.	199.	405849.	28.	28.4
D	6.0	30.0	192.7	0.00	1.00	0.00	354.	258.	612894.	45.	1209.9
A	3.0	0.3	193.0	0.00	1.00	0.00	354.	258.	614155.	45.	30.9
D	3.0	13.0	206.0	0.00	1.00	0.00	361.	278.	664329.	51.	426.8
A	0.0	0.3	206.3	0.00	1.00	0.00	362.	278.	664872.	51.	33.4
X	0.0	0.0	0.0	0.00	1.00	0.00	362.	278.	664872.	51.	0.0

DATA (1d) NEDU p. B-3:

90 fswg / 120 min:

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Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN). All except first and those with a gas switch include travel time to stop																		TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	
		BOTTOM MIX											(50)	(50)	(50)	(50)	(50)	(50)	(100)	(100)	
90	10																			0	
Max O_2 = 34.9%	20																			0	
Min O_2 = 21.0%	30																		3	3	1
	40																		5	5	1
	60																		3	35	2
	80												1						2	65	3
	100												1						2	90	3
	120												1						13	112	4

```
 Yr: 2024 Mon: 01 D: 18 Hr: 15 Min: 28  Version: 3_11     , 02/2024
90 fswg NEDU max O2
   DEPTH    TIME   SUM.TIME   N     O     HE     CNS    OTU     K CNS      K POT
X    0.0     0.0       0.0  0.79 0.21 0.00     0.     0.        0.        0.
D   27.6   120.0     120.0  -.00 0.34 0.66    67.   176.    74687.       12.
D   27.6     1.0     121.0  0.50 0.50 0.00    70.   178.    79377.       13.
A    9.2     2.0     123.0  0.50 0.50 0.00    71.   180.    80344.       13.
D    9.2    13.0     136.0  0.00 1.00 0.00   123.   211.   161545.       21.
A    6.1     0.3     136.3  0.00 1.00 0.00   123.   212.   162888.       21.
D    6.1    98.0     234.3  0.00 1.00 0.00   368.   405.   807475.       88.
A    0.0     0.7     235.0  0.00 1.00 0.00   369.   405.   808661.       89.
X    0.0     0.0       0.0  0.00 1.00 0.00   369.   405.   808661.       89.
```

```
 Yr: 2024 Mon: 01 D: 18 Hr: 15 Min: 09  Version: 3_11     , 02/2024
  98 fswg NEDU min o2
   DEPTH    TIME   SUM.TIME   N     O     HE     CNS    OTU     K CNS      K POT
X    0.0     0.0       0.0  0.79 0.21 0.00     0.     0.        0.        0.
D   27.6   120.0     120.0  -.00 0.21 0.79    27.    78.     2820.        1.
D   27.6     1.0     121.0  0.50 0.50 0.00    30.    80.     3789.        2.
A   12.2     1.7     122.7  0.50 0.50 0.00    31.    82.     4083.        2.
A    9.9     0.2     122.9  0.00 1.00 0.00    32.    83.     4414.        2.
D    9.2    13.0     135.9  0.00 1.00 0.00    84.   114.    34193.        5.
A    6.1     0.3     136.2  0.00 1.00 0.00    85.   115.    34812.        5.
D    6.1    98.0     234.2  0.00 1.00 0.00   330.   308.   464555.       50.
A    0.0     0.7     234.9  0.00 1.00 0.00   330.   309.   465454.       51.
X    0.0     0.0       0.0  0.00 1.00 0.00   330.   309.   465454.       51.
```

DATA (2a) DCIEM p. 2A-11:

170 ft / 60 min

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170	40	2	-	-	-	-	-	-	3	3	3	6	10	76**	114
	45	2	-	-	-	-	-	1	3	3	4	7	12	84**	127
	50	2	-	-	-	-	-	1	3	3	5	9	13	90***	142
	55	2	-	-	-	-	-	2	3	3	7	10	15	91***	149
	60	2	-	-	-	-	-	2	3	4	8	11	21	94***	161

170 feet DCIEM

	DEPTH	TIME	SUM.TIME	N	O	HE	CNS	OTU	K CNS	K POT
X	0.0	0.0	0.0	0.79	0.21	0.00	0.	0.	0.	0.
D	52.2	60.0	60.0	0.00	0.16	0.84	20.	60.	3328.	1.
A	27.6	1.8	61.8	0.79	0.21	0.00	20.	61.	3418.	1.
D	27.6	2.0	63.8	0.79	0.21	0.00	21.	63.	3521.	1.
A	24.5	0.2	64.0	0.79	0.21	0.00	21.	63.	3530.	1.
D	24.6	3.0	67.0	0.79	0.21	0.00	22.	64.	3648.	1.
A	21.4	0.2	67.2	0.79	0.21	0.00	22.	64.	3655.	1.
D	21.5	4.0	71.2	0.79	0.21	0.00	22.	66.	3772.	1.
A	18.4	0.2	71.4	0.79	0.21	0.00	22.	66.	3777.	1.
D	18.4	8.0	79.4	0.79	0.21	0.00	24.	68.	3946.	1.
A	15.3	0.2	79.6	0.79	0.21	0.00	24.	68.	3949.	1.
D	15.3	11.0	90.6	0.79	0.21	0.00	24.	69.	4110.	1.
A	12.2	0.2	90.9	0.79	0.21	0.00	24.	69.	4112.	1.
D	12.3	21.0	111.9	0.79	0.21	0.00	24.	69.	4315.	1.
A	9.2	0.2	112.1	0.00	1.00	0.00	25.	70.	4581.	2.
D	9.2	94.0	206.1	0.00	1.00	0.00	401.	296.	848858.	66.
A	0.0	0.7	206.8	0.00	1.00	0.00	401.	297.	850069.	66.
X	0.0	0.0	0.0	0.00	1.00	0.00	401.	297.	850069.	66.

DATA (2b) NEDU p. B-6:

170 fswg / 60 min

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Yr: 2024 Mon: 01 D: 17 Hr: 13 Min: 36 Version: 3_11 , 02/2024

170 fswg NEDU

	DEPTH	TIME	SUM.TIME	N	O	HE	CNS	OTU	K CNS	K POT
X	0.0	0.0	0.0	0.79	0.21	0.00	0.	0.	0.	0.
D	52.2	60.0	60.0	0.00	0.16	0.84	20.	60.	3365.	1.
A	27.6	2.6	62.6	0.00	0.16	0.84	20.	61.	3419.	1.
D	27.6	1.0	63.6	0.00	0.16	0.84	21.	61.	3440.	1.
D	27.6	3.0	66.6	0.50	0.50	0.00	31.	68.	7054.	1.
A	24.5	0.3	67.0	0.50	0.50	0.00	32.	69.	7414.	2.
D	24.6	2.0	69.0	0.50	0.50	0.00	37.	73.	9753.	2.
A	21.4	0.3	69.3	0.50	0.50	0.00	38.	74.	10062.	2.
D	21.5	2.0	71.3	0.50	0.50	0.00	43.	78.	11999.	2.
A	18.4	0.3	71.7	0.50	0.50	0.00	43.	78.	12236.	2.
D	18.4	3.0	74.7	0.50	0.50	0.00	45.	83.	14494.	2.
A	15.6	0.3	75.0	0.50	0.50	0.00	45.	84.	14661.	3.
D	15.3	9.0	84.0	0.50	0.50	0.00	50.	97.	19875.	3.
A	12.2	0.3	84.3	0.50	0.50	0.00	50.	97.	20010.	3.
D	12.3	10.0	94.3	0.50	0.50	0.00	55.	109.	24250.	4.
A	9.2	0.3	94.6	0.00	1.00	0.00	56.	110.	25195.	4.
D	9.2	29.0	123.6	0.00	1.00	0.00	172.	180.	178868.	18.
A	6.1	0.3	124.0	0.00	1.00	0.00	173.	181.	180280.	18.
D	6.1	98.0	222.0	0.00	1.00	0.00	418.	374.	845396.	82.
A	0.0	0.7	222.6	0.00	1.00	0.00	418.	374.	846609.	83.
X	0.0	0.0	0.0	0.00	1.00	0.00	418.	374.	846609.	83.

170	10																				
Max O_2 = 21.2%	20																				

Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW)																		TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		STOP TIMES (MIN). All except first and those with a gas switch include travel time to stop																			
		200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	
		BOTTOM MIX											(50)	(50)	(50)	(50)	(50)	(50)	(100)	(100)	
Min O_2 = 16.0%	30												4						8	44	56	2
	40												3	2	2	3			16	66	92	3
	60												4	2	2	3	9	10	29	98	157	5

DATA (2c) DIVE 3_11:

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170 fswg ➔ 52.20 m
ascent to 30 m, 2 + 5 min stop and gas-switch ➔ Air

```
 deco prognosis with gradient factors:   GF HI=  0.9000 GF LO=  0.9000
33m stop  prognosis deco time:      2.0  GF =  0.9000  comp.#:  6
30m stop  prognosis deco time:      5.0  GF =  0.9000  comp.#:  7
27m stop  prognosis deco time:      2.0  GF =  0.9000  comp.#:  7
24m stop  prognosis deco time:      7.0  GF =  0.9000  comp.#:  8
21m stop  prognosis deco time:      6.0  GF =  0.9000  comp.#:  8
18m stop  prognosis deco time:      8.0  GF =  0.9000  comp.#:  8
15m stop  prognosis deco time:     15.0  GF =  0.9000  comp.#:  9
12m stop  prognosis deco time:     18.0  GF =  0.9000  comp.#: 10
```

ascent to 9 m, switch to .9 / 0.1 O_2 /N_2 for TTS calculation only:
total TTS : (Air) 63 + (O_2) 95 = 158 + ascent time

```
 deco prognosis:
   9m stop  prognosis deco time:      6.0  comp.#: 11
   6m stop  prognosis deco time:     78.0  comp.#: 14
TTS =     85.0
 deco prognosis with gradient factors:   GF HI=  0.9000 GF LO=  0.9000
 9m stop  prognosis deco time:     10.0  GF =  0.9000  comp.#: 11
 6m stop  prognosis deco time:     84.0  GF =  0.9000  comp.#: 14
TTS =     94.9
```

fO_2 = 1.0 only for K-value assessment:

```
 deco prognosis with gradient factors:   GF HI=  0.9000 GF LO=  0.9000
 9m stop  prognosis deco time:      9.0  GF =  0.9000  comp.#: 11
 6m stop  prognosis deco time:     76.0  GF =  0.9000  comp.#: 14
TTS =     85.0
```

DATA (2d) DIVE 3_11:

170 fswg ➔ 52.20 m, with GF Hi = GF Lo = 0.9

SUB
MARINE
CONSULTING

Yr: 2024 Mon: 01 D: 21 Hr: 15 Min: 06 Version: 3_11 , 02/2024
170 fswg with ZH-L 16 C and GF Hi = GF Lo = 0.9

	DEPTH	TIME	SUM.TIME	N	O	HE	CNS	OTU	K CNS	K POT
X	0.0	0.0	0.0	0.79	0.21	0.00	0.	0.	0.	0.
D	52.2	60.0	60.0	0.00	0.16	0.84	20.	60.	3369.	1.
A	30.0	2.4	62.4	0.00	0.16	0.84	20.	61.	3430.	1.
D	30.0	7.0	69.4	0.79	0.21	0.00	22.	66.	3891.	1.
A	27.0	0.3	69.7	0.79	0.21	0.00	22.	67.	3907.	1.
D	27.0	2.0	71.7	0.79	0.21	0.00	23.	68.	4013.	1.
A	24.0	0.3	72.0	0.79	0.21	0.00	23.	68.	4025.	1.
D	24.0	7.0	79.0	0.79	0.21	0.00	25.	72.	4309.	1.
A	21.0	0.3	79.4	0.79	0.21	0.00	25.	72.	4318.	1.
D	21.0	6.0	85.4	0.79	0.21	0.00	26.	74.	4501.	1.
A	18.0	0.3	85.7	0.79	0.21	0.00	26.	74.	4508.	1.
D	18.0	8.0	93.7	0.79	0.21	0.00	27.	76.	4684.	2.
A	15.0	0.3	94.0	0.79	0.21	0.00	27.	76.	4689.	2.
D	15.0	15.0	109.0	0.79	0.21	0.00	27.	78.	4919.	2.
A	12.0	0.3	109.3	0.79	0.21	0.00	27.	78.	4922.	2.
D	12.0	18.0	127.3	0.79	0.21	0.00	27.	78.	5104.	2.
A	9.0	0.3	127.6	0.00	1.00	0.00	28.	78.	5517.	2.
D	9.0	10.0	137.6	0.00	1.00	0.00	61.	102.	26270.	4.
A	6.0	0.3	138.0	0.00	1.00	0.00	62.	103.	26785.	4.
D	6.0	84.0	222.0	0.00	1.00	0.00	249.	266.	331325.	38.
A	0.0	0.6	222.6	0.00	1.00	0.00	249.	267.	332068.	38.
X	0.0	0.0	0.0	0.00	1.00	0.00	249.	267.	332068.	38.

DATA (3a) DCIEM p. 2A-13:

SUB
MARINE
CONSULTING

230	25	3	-	-	-	-	2	2	3	3	2	5	9	71**	111
	30	2	-	-	-	1	2	3	2	3	3	8	11	85**	131
	35	2	-	-	-	2	2	3	3	2	7	8	15	90***	150
	40	2	-	-	1	2	3	2	3	4	8	10	22	97***	170

Yr: 2024 Mon: 01 D: 17 Hr: 17 Min: 50 Version: 3_11 , 02/2024
230 feet DCIEM

	DEPTH	TIME	SUM.TIME	N	O	HE	CNS	OTU	K CNS	K POT
X	0.0	0.0	0.0	0.79	0.21	0.00	0.	0.	0.	0.
D	70.6	40.0	40.0	0.00	0.16	0.84	22.	59.	8614.	1.
A	36.8	2.4	42.4	0.00	0.16	0.84	23.	60.	8778.	1.
D	36.8	1.0	43.4	0.79	0.21	0.00	23.	61.	8953.	1.
A	33.7	0.2	43.6	0.79	0.21	0.00	23.	62.	8984.	1.
D	33.8	2.0	45.6	0.79	0.21	0.00	24.	63.	9265.	2.
A	30.7	0.2	45.9	0.79	0.21	0.00	24.	63.	9289.	2.
D	30.7	3.0	48.9	0.79	0.21	0.00	25.	66.	9624.	2.
A	27.6	0.2	49.1	0.79	0.21	0.00	25.	66.	9643.	2.
D	27.6	2.0	51.1	0.79	0.21	0.00	25.	67.	9817.	2.
A	24.5	0.2	51.3	0.79	0.21	0.00	25.	67.	9831.	2.
D	24.6	3.0	54.3	0.79	0.21	0.00	26.	69.	10028.	2.
A	21.4	0.2	54.5	0.79	0.21	0.00	26.	69.	10039.	2.
D	21.5	4.0	58.5	0.79	0.21	0.00	27.	71.	10233.	2.
A	18.4	0.2	58.8	0.79	0.21	0.00	27.	71.	10241.	2.
D	18.4	8.0	66.8	0.79	0.21	0.00	28.	73.	10517.	2.
A	15.3	0.2	67.0	0.79	0.21	0.00	28.	73.	10523.	2.
D	15.3	10.0	77.0	0.79	0.21	0.00	28.	74.	10761.	2.
A	12.2	0.2	77.2	0.79	0.21	0.00	28.	74.	10764.	2.
D	12.3	22.0	99.2	0.79	0.21	0.00	28.	74.	11106.	2.
A	9.2	0.2	99.4	0.00	1.00	0.00	29.	74.	11530.	2.
D	9.2	97.0	196.4	0.00	1.00	0.00	417.	308.	976694.	75.
A	0.0	0.7	197.1	0.00	1.00	0.00	417.	308.	977993.	75.
X	0.0	0.0	0.0	0.00	1.00	0.00	417.	308.	977993.	75.

DATA (3b) NEDU p. B-8:

SUB MARINE CONSULTING

Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN). All except first and those with a gas switch include travel time to stop																		TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	
		BOTTOM MIX											(50)	(50)	(50)	(50)	(50)	(50)	(100)	(100)	
230	10												1						9		10	1
Max O_2 = 16.3%	20												6	3					14	45	68	2
Min O_2 = 12.0%	30												10	3	2	4	12	9	16	84	140	4
	40												13	7	12	11	10	9	30	107	199	5

```
 Yr: 2024 Mon: 01 D: 17 Hr: 18 Min: 17  Version: 3_11     , 02/2024
230 fswg NEDU min O2!
   DEPTH   TIME   SUM.TIME  N    O    HE    CNS   OTU    K CNS     K POT
X    0.0    0.0      0.0  0.79 0.21 0.00    0.    0.        0.       0.
D   70.6   40.0     40.0  0.00 0.12 0.88   13.   38.     1232.       0.
A   36.8    3.6     43.6  0.00 0.12 0.88   14.   39.     1268.       0.
D   27.6   13.0     56.6  0.50 0.50 0.00   57.   70.    21143.       2.
A   24.5    0.3     57.0  0.50 0.50 0.00   58.   70.    21763.       2.
D   24.6    7.0     64.0  0.50 0.50 0.00   78.   85.    36792.       4.
A   21.4    0.3     64.3  0.50 0.50 0.00   79.   86.    37390.       4.
D   21.5   12.0     76.3  0.50 0.50 0.00  106.  109.    61869.       6.
A   18.4    0.3     76.6  0.50 0.50 0.00  106.  109.    62407.       6.
D   18.4   11.0     87.6  0.50 0.50 0.00  114.  128.    81595.       9.
A   15.3    0.3     88.0  0.50 0.50 0.00  114.  128.    82017.       9.
D   15.3   10.0     98.0  0.50 0.50 0.00  120.  143.    95166.      11.
A   12.2    0.3     98.3  0.50 0.50 0.00  120.  143.    95461.      11.
D   12.3    9.0    107.3  0.50 0.50 0.00  124.  154.   103560.      12.
A    9.2    0.3    107.6  0.00 1.00 0.00  126.  155.   105505.      12.
D    9.2   30.0    137.6  0.00 1.00 0.00  246.  227.   357750.      32.
A    6.1    0.3    138.0  0.00 1.00 0.00  246.  228.   359747.      32.
D    6.1  107.0    245.0  0.00 1.00 0.00  514.  438.  1299817.     121.
A    0.0    0.7    245.6  0.00 1.00 0.00  514.  439.  1301322.     121.
X    0.0    0.0      0.0  0.00 1.00 0.00  514.  439.  1301322.     121.
```

DATA (3c) DIVE 3_11:

SUB
MARINE
CONSULTING

230 fwsg ➔ 70.62 m

```
 deco prognosis with gradient factors:   GF HI=  0.9000 GF LO=  0.9000
42m stop  prognosis deco time:      1.0  GF =  0.9000  comp.#:  5
39m stop  prognosis deco time:      4.0  GF =  0.9000  comp.#:  6
36m stop  prognosis deco time:      1.0  GF =  0.9000  comp.#:  6
33m stop  prognosis deco time:      4.0  GF =  0.9000  comp.#:  6
30m stop  prognosis deco time:      2.0  GF =  0.9000  comp.#:  7
27m stop  prognosis deco time:      5.0  GF =  0.9000  comp.#:  7
24m stop  prognosis deco time:      4.0  GF =  0.9000  comp.#:  7
21m stop  prognosis deco time:      8.0  GF =  0.9000  comp.#:  8
18m stop  prognosis deco time:      7.0  GF =  0.9000  comp.#:  8
15m stop  prognosis deco time:     13.0  GF =  0.9000  comp.#:  9
12m stop  prognosis deco time:     16.0  GF =  0.9000  comp.#: 10
```

O_2 decompression: @ 9 m / 12 min
@ 6 m / 81 min

TTS ➔ 65 (Air) + 93 (O_2) = 158 (fO_2: 0.9) + 8 (ascent time) = 166

DATA (3d) DIVE 3_11:

SUB
MARINE
CONSULTING

230 fwsg ➔ 70.62 m

230 fwsg ZH-L 16 C GF 0.9

	DEPTH	TIME	SUM.TIME	N	O	HE	CNS	OTU	K CNS	K POT
X	0.0	0.0	0.0	0.79	0.21	0.00	0.	0.	0.	0.
D	70.6	40.0	40.0	0.00	0.16	0.84	22.	59.	8726.	1.
A	39.0	3.4	43.4	0.00	0.16	0.84	23.	61.	9001.	1.
D	39.0	5.0	48.4	0.79	0.21	0.00	25.	67.	10060.	2.
A	36.0	0.3	48.7	0.79	0.21	0.00	25.	67.	10116.	2.
D	36.0	1.0	49.7	0.79	0.21	0.00	26.	68.	10293.	2.
A	33.0	0.3	50.0	0.79	0.21	0.00	26.	68.	10339.	2.
D	33.0	4.0	54.0	0.79	0.21	0.00	27.	72.	10913.	2.
A	30.0	0.3	54.4	0.79	0.21	0.00	27.	72.	10950.	2.
D	30.0	2.0	56.4	0.79	0.21	0.00	27.	73.	11179.	2.
A	27.0	0.3	56.7	0.79	0.21	0.00	27.	73.	11207.	2.
D	27.0	5.0	61.7	0.79	0.21	0.00	29.	77.	11654.	2.
A	24.0	0.3	62.0	0.79	0.21	0.00	29.	77.	11676.	2.
D	24.0	4.0	66.0	0.79	0.21	0.00	29.	79.	11948.	2.
A	21.0	0.3	66.3	0.79	0.21	0.00	30.	79.	11965.	2.
D	21.0	8.0	74.3	0.79	0.21	0.00	31.	82.	12369.	2.
A	18.0	0.3	74.7	0.79	0.21	0.00	31.	82.	12381.	2.
D	18.0	7.0	81.7	0.79	0.21	0.00	32.	84.	12635.	2.
A	15.0	0.3	82.0	0.79	0.21	0.00	32.	84.	12643.	2.
D	15.0	13.0	95.0	0.79	0.21	0.00	32.	85.	12968.	3.
A	12.0	0.3	95.3	0.79	0.21	0.00	32.	85.	12973.	3.
D	12.0	16.0	111.3	0.79	0.21	0.00	32.	85.	13235.	3.
A	9.0	0.3	111.6	0.00	1.00	0.00	33.	86.	13895.	3.
D	9.0	12.0	123.6	0.00	1.00	0.00	73.	114.	49836.	7.
A	6.0	0.3	123.9	0.00	1.00	0.00	74.	115.	50545.	7.
D	6.0	81.0	204.9	0.00	1.00	0.00	254.	273.	386955.	42.
A	0.0	0.6	205.6	0.00	1.00	0.00	254.	274.	387757.	42.
X	0.0	0.0	0.0	0.00	1.00	0.00	254.	274.	387757.	42.

DATA (3e) DIVE 3_11:

SUB
MARINE
CONSULTING

230 fwsg ➔ 70.62 m with GF 0.8; Heliox ➔ 30 m, then EAN50 ➔ 12 m, then oxygen decompression
TTS ➔ 62 + 94 + ascent time (8) = 164

230 fswg ZH-L 16 C GF 0.8

	DEPTH	TIME	SUM.TIME	N	O	HE	CNS	OTU	K CNS	K POT
X	0.0	0.0	0.0	0.79	0.21	0.00	0.	0.	0.	0.
D	70.6	40.0	40.0	0.00	0.16	0.84	22.	59.	8726.	1.
A	39.0	3.4	43.4	0.00	0.16	0.84	23.	61.	9001.	1.
D	39.0	2.0	45.4	0.00	0.16	0.84	23.	63.	9165.	2.
A	36.0	0.3	45.7	0.00	0.16	0.84	23.	63.	9187.	2.
D	36.0	3.0	48.7	0.00	0.16	0.84	24.	64.	9387.	2.
A	33.0	0.3	49.0	0.00	0.16	0.84	24.	65.	9405.	2.
D	33.0	4.0	53.0	0.00	0.16	0.84	25.	66.	9620.	2.
A	30.0	0.3	53.4	0.50	0.50	0.00	26.	67.	10289.	2.
D	30.0	6.0	59.4	0.50	0.50	0.00	50.	82.	26839.	3.
A	27.0	0.3	59.7	0.50	0.50	0.00	51.	83.	27690.	3.
D	27.0	3.0	62.7	0.50	0.50	0.00	61.	90.	36230.	4.
A	24.0	0.3	63.0	0.50	0.50	0.00	62.	91.	36969.	4.
D	24.0	5.0	68.0	0.50	0.50	0.00	75.	101.	49382.	5.
A	21.0	0.3	68.3	0.50	0.50	0.00	75.	102.	50011.	5.
D	21.0	6.0	74.3	0.50	0.50	0.00	82.	113.	62447.	7.
A	18.0	0.3	74.7	0.50	0.50	0.00	82.	113.	62948.	7.
D	18.0	7.0	81.7	0.50	0.50	0.00	87.	125.	74303.	8.
A	15.0	0.3	82.0	0.50	0.50	0.00	87.	125.	74674.	8.
D	15.0	11.0	93.0	0.50	0.50	0.00	93.	141.	87895.	10.
A	12.0	0.3	93.3	0.50	0.50	0.00	93.	141.	88157.	10.
D	12.0	15.0	108.3	0.50	0.50	0.00	99.	159.	100757.	12.
A	9.0	0.3	108.6	0.00	1.00	0.00	100.	160.	102563.	12.
D	9.0	11.0	119.6	0.00	1.00	0.00	137.	186.	173753.	18.
A	6.0	0.3	119.9	0.00	1.00	0.00	138.	187.	175075.	19.
D	6.0	83.0	202.9	0.00	1.00	0.00	322.	348.	681388.	70.
A	0.0	0.6	203.6	0.00	1.00	0.00	322.	349.	682452.	70.
X	0.0	0.0	0.0	0.00	1.00	0.00	322.	349.	682452.	70.

DATA (3f) DIVE 3_11:

SUB
MARINE
CONSULTING

230 fwsg ➔ 70.62 m with GF 0.8

```
 deco prognosis with gradient factors:   GF HI=  0.8000 GF LO=  0.8000
39m stop  prognosis deco time:      2.0  GF =  0.8000  comp.#:  5
36m stop  prognosis deco time:      3.0  GF =  0.8000  comp.#:  6
33m stop  prognosis deco time:      4.0  GF =  0.8000  comp.#:  7
30m stop  prognosis deco time:      7.0  GF =  0.8000  comp.#:  7
```

```
 deco prognosis with gradient factors:   GF HI=  0.8000 GF LO=  0.8000
33m stop  prognosis deco time:      3.0  GF =  0.8000  comp.#:  7
30m stop  prognosis deco time:      3.0  GF =  0.8000  comp.#:  7
27m stop  prognosis deco time:      3.0  GF =  0.8000  comp.#:  7
24m stop  prognosis deco time:      5.0  GF =  0.8000  comp.#:  8
21m stop  prognosis deco time:      6.0  GF =  0.8000  comp.#:  8
18m stop  prognosis deco time:      7.0  GF =  0.8000  comp.#:  9
15m stop  prognosis deco time:     11.0  GF =  0.8000  comp.#:  9
12m stop  prognosis deco time:     15.0  GF =  0.8000  comp.#: 10
```

```
 deco prognosis:
   9m stop  prognosis deco time:      3.0  comp.#: 11
   6m stop  prognosis deco time:     70.0  comp.#: 14
TTS =     74.0
 deco prognosis with gradient factors:   GF HI=  0.8000 GF LO=  0.8000
 9m stop  prognosis deco time:     11.0  GF =  0.8000  comp.#: 11
 6m stop  prognosis deco time:     83.0  GF =  0.8000  comp.#: 14
TTS =     94.9
```

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MARINE
CONSULTING

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