Implementation of Dual Phase Decompression Models in Tables & Meters for technical diving

23th Capita Selecta Duikgeneeskunde

Amsterdam, 03/17/2018:

21st. Century Decompression Theory

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GROUP

TEL AVIV – SAN FRANCISCO – STUTTGART

WWW.SMC-DE.COM

Implementation of Dual Phase Decompression Models in Tables & Meters for technical diving

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Agenda:

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- **Dive tables versus dive computers in technical diving**
- **Shortcomings of dive computers**
- **The controversy around “Deep Stops”:**
  “My model is better than yours …”
- **Solution to this dilemma:**
  statistically based decompression tables / P(DCS)
- **In-sights from real world diving:**
  → DAN DSG database (35.000 dives)
- **DJRS, the Dive Jump Reporting System;**
  → USN (0,8 million dives)

Test „Dive“: 42 m, 25 min, Air; comparison with **desktop deco software:**

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→ Subsurface
→ DecoPlanner
→ (1st.) Excel-Version

and dive computers:

→ Ratio iX3m
→ Scubapro / Uwatec G2 (Galileo 2)

VPM Implementations:

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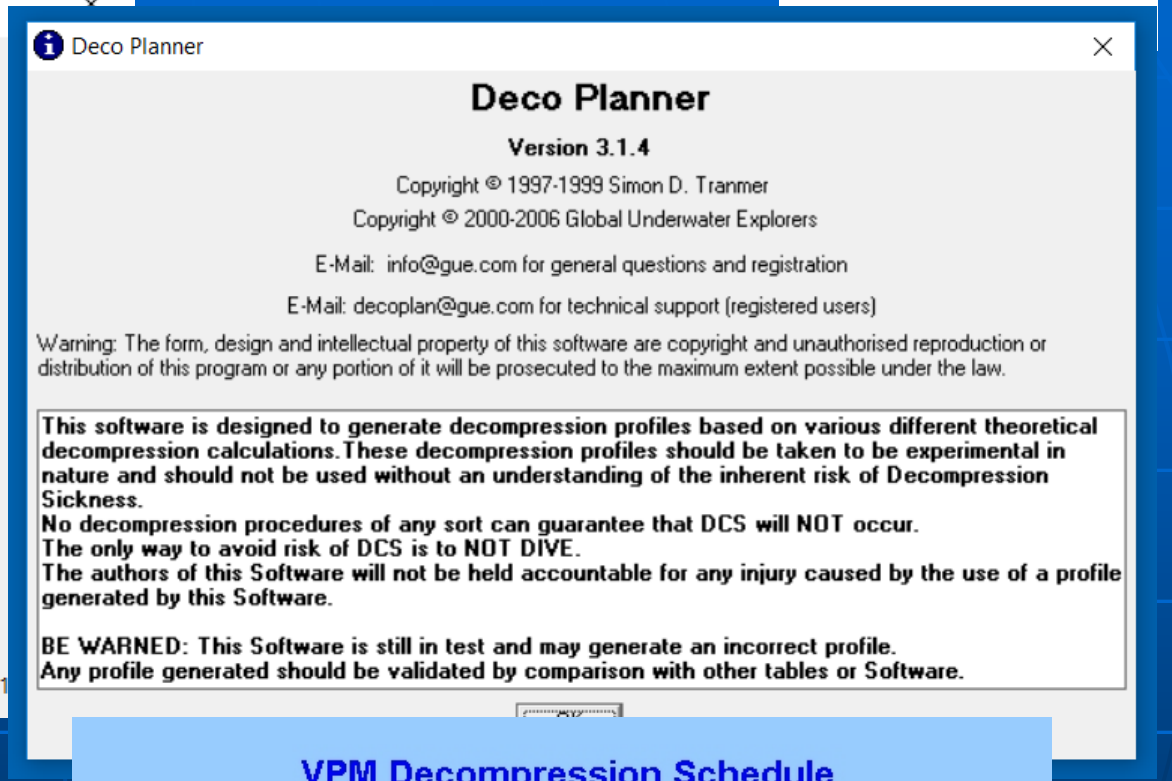
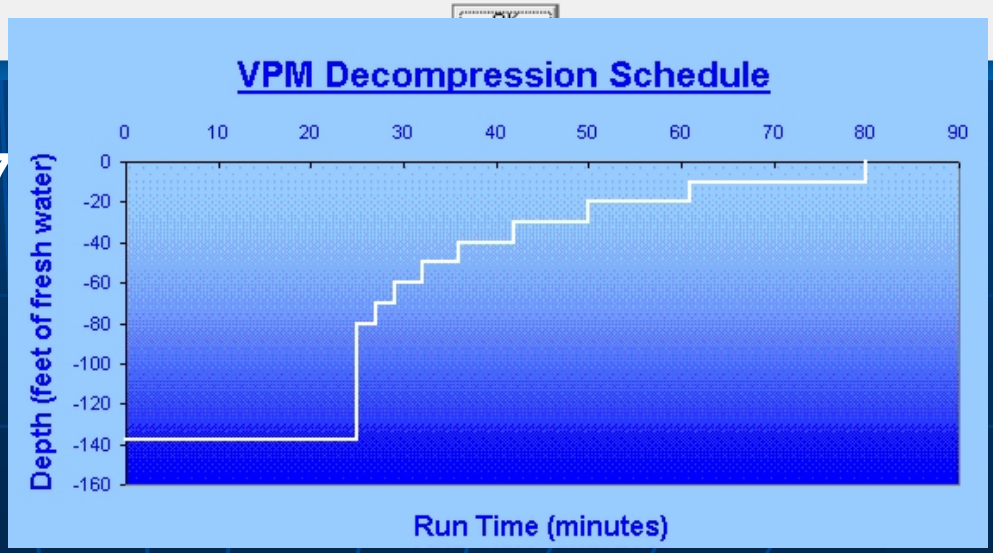


… with:
Subsurface 4.7.4 (11/2017
https://subsurface-divelog.org

DecoPlanner 3.1.4



Tauchplandetails

Subsurface (4.7.4.0) Plan erstellt am 28.11.17
Runtime: 73min

	Tiefe	Dauer	Runtime	Gas
↘	42m	2min	2min	Luft
→	42m	25min	27min	
↗	21m	2min	29min	
-	21m	1min	30min	
↗	18m	0min	30min	
-	18m	2min	32min	
↗	15m	0min	32min	
-	15m	3min	35min	
↗	12m	0min	35min	
-	12m	5min	40min	
↗	9m	0min	40min	
-	9m	6min	46min	
↗	6m	0min	46min	
-	6m	10min	56min	
↗	3m	0min	56min	
-	3m	17min	73min	
↗	0m	0min	73min	

CNS: 12%
OTU: 37

42 m, 25 min, Air:

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Conservatism:

0 → decotime:	**46‘**
1 →	**50‘**
2 →	**56‘**
3 →	**63‘**
4 →	**72‘**

n, 25 min, Air:

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Runtime: 55min

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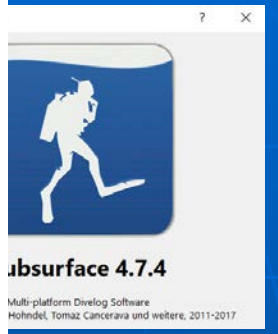
↗	9m	4min	31min	
-	9m	1min	32min	
↗	6m	0min	32min	
-	6m	7min	39min	
↗	3m	0min	39min	
-	3m	16min	55min	
↗	0m	0min	55min	

CNS: 11%
OTU: 35

Dekomodell: Bühlmann ZHL-16C mit GF niedrig = 100% und GF hoch = 100%
Oberflächendruck: 1013mbar (0m)



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Test „Dive“: 42 m, 25 min, Air:

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Stop depth [m]	VPM Cons. = 0	ZH-L16 GF Hi/Lo = 1.0
21	1	-
18	2	-
15	3	-
12	5	-
9	6	1
6	10	7
3	17	16

Test „Dive“: 42 m, 25 min, Air:

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Stop depth [m]	VPM Cons. = 0	ZH-L16 GF Hi/Lo = 1.0
21	1	-
18	2	-
15	3	-
12	5	-
9	6	1
6	10	7
3	17	16

Tauchplandetails

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-	15m	3min	35min	
↗	12m	0min	35min	
-	12m	5min	40min	
↗	9m	0min	40min	
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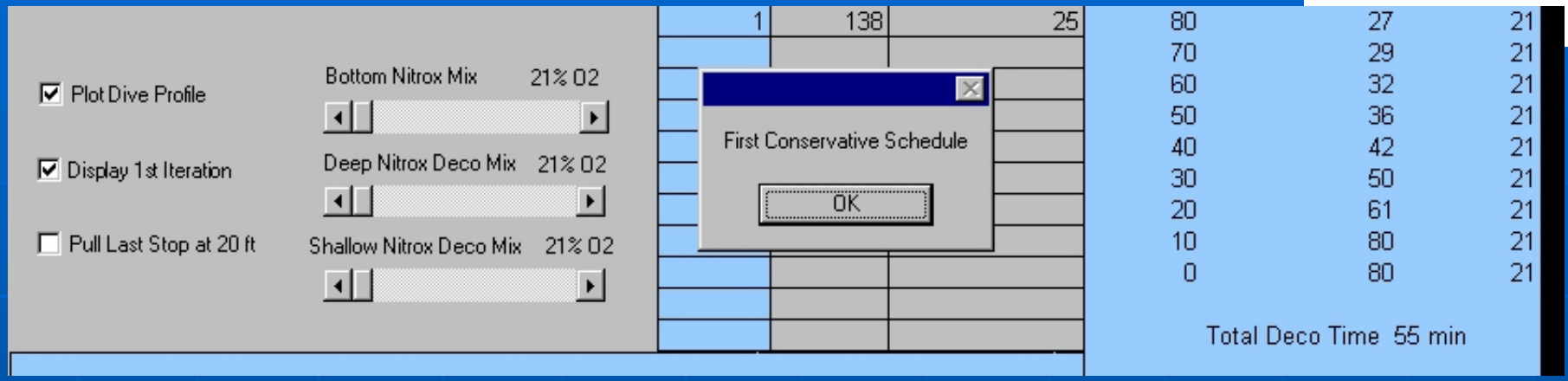
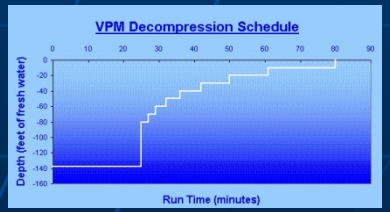


INPUT			OUTPUT		
Dive Profile			Decompression Profile		
Stage	Depth(ft)	Run-Time(min)	Depth(ft)	Run-Time(min)	Gas % O2
1	138	25	70	27	21
			60	29	21
			50	32	21
			40	36	21
			30	42	21
			20	50	21
			10	64	21
			0	64	21
			Total Deco Time 39 min		



Test „Dive“: 42 m, 25 min, Air:

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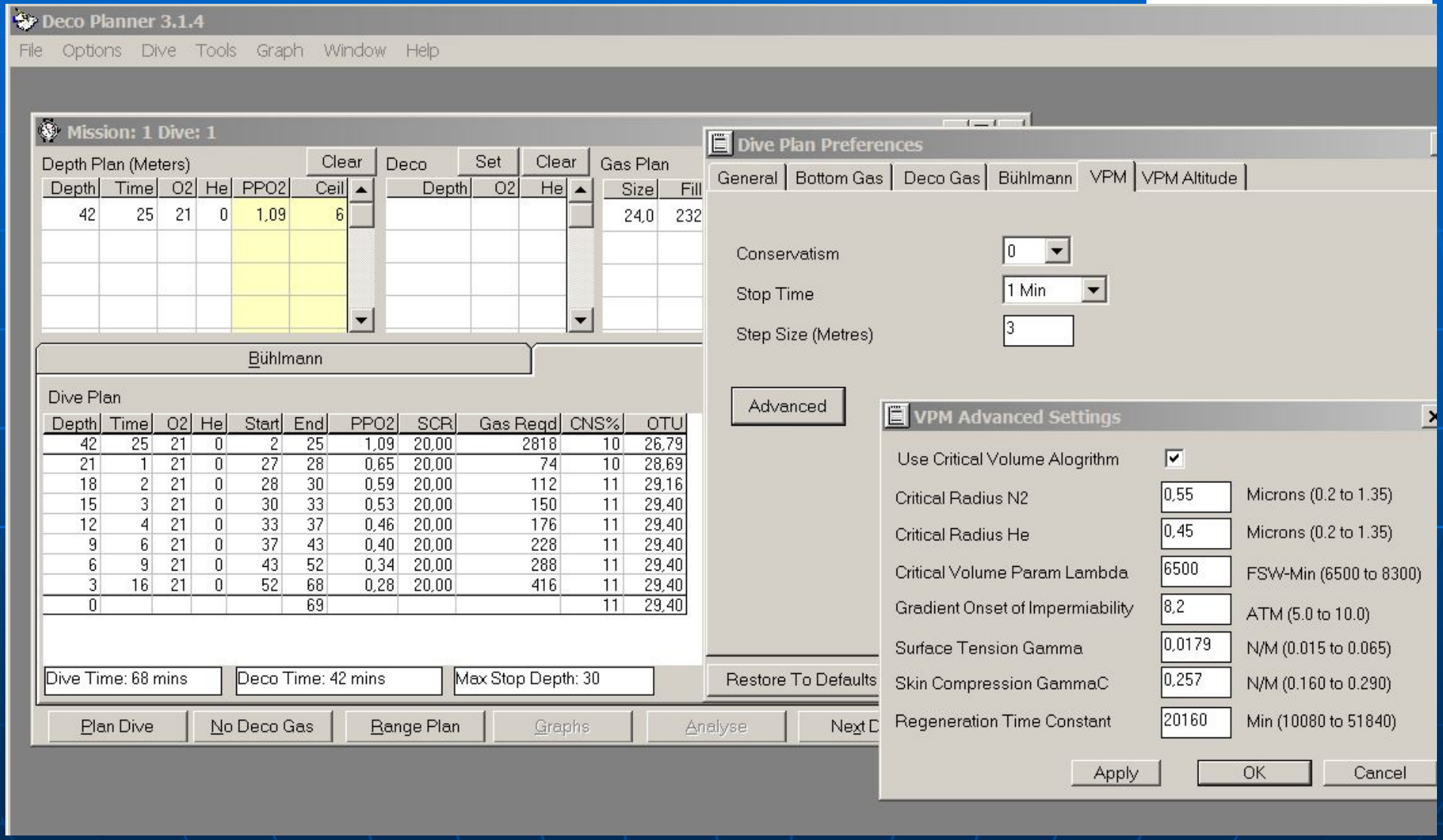

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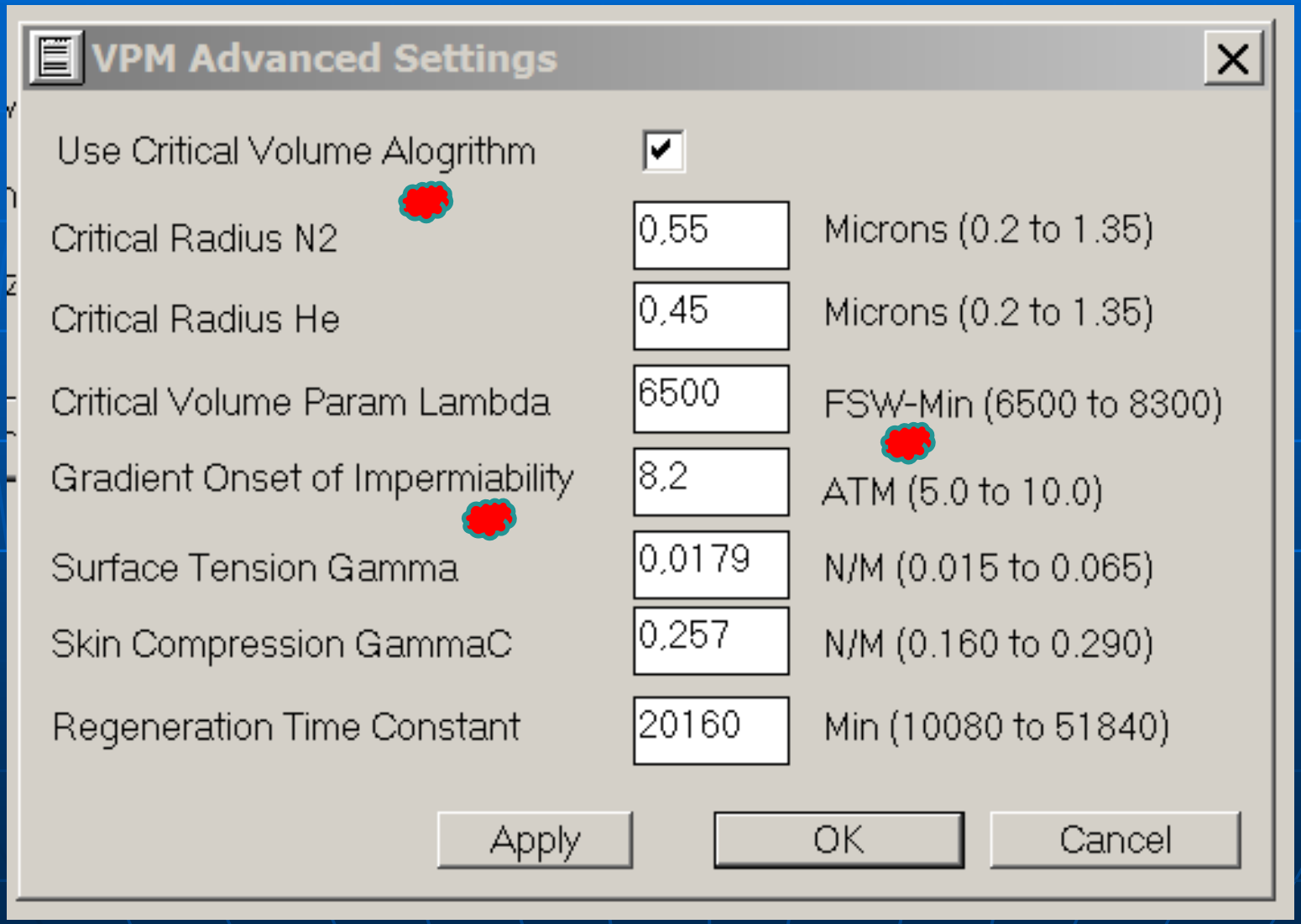

Test „Dive“: 42 m, 25 min, Air:

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Dive Plan

Depth	Time	O2	He	Start	End	PPO2	SCR	Gas Reqd	CNS%	OTU
42	25	21	0	2	25	1,09	20,00	2818	10	26,79
21	1	21	0	27	28	0,65	20,00	74	10	28,69
18	2	21	0	28	30	0,59	20,00	112	11	29,16
15	3	21	0	30	33	0,53	20,00	150	11	29,40
12	4	21	0	33	37	0,46	20,00	176	11	29,40
9	6	21	0	37	43	0,40	20,00	228	11	29,40
6	9	21	0	43	52	0,34	20,00	288	11	29,40
3	16	21	0	52	68	0,28	20,00	416	11	29,40
0					69				11	29,40

Dive Time: 68 mins | Deco Time: 42 mins | Max Stop Depth: 30

Test „Dive“: 42 m, 25 min, Air:

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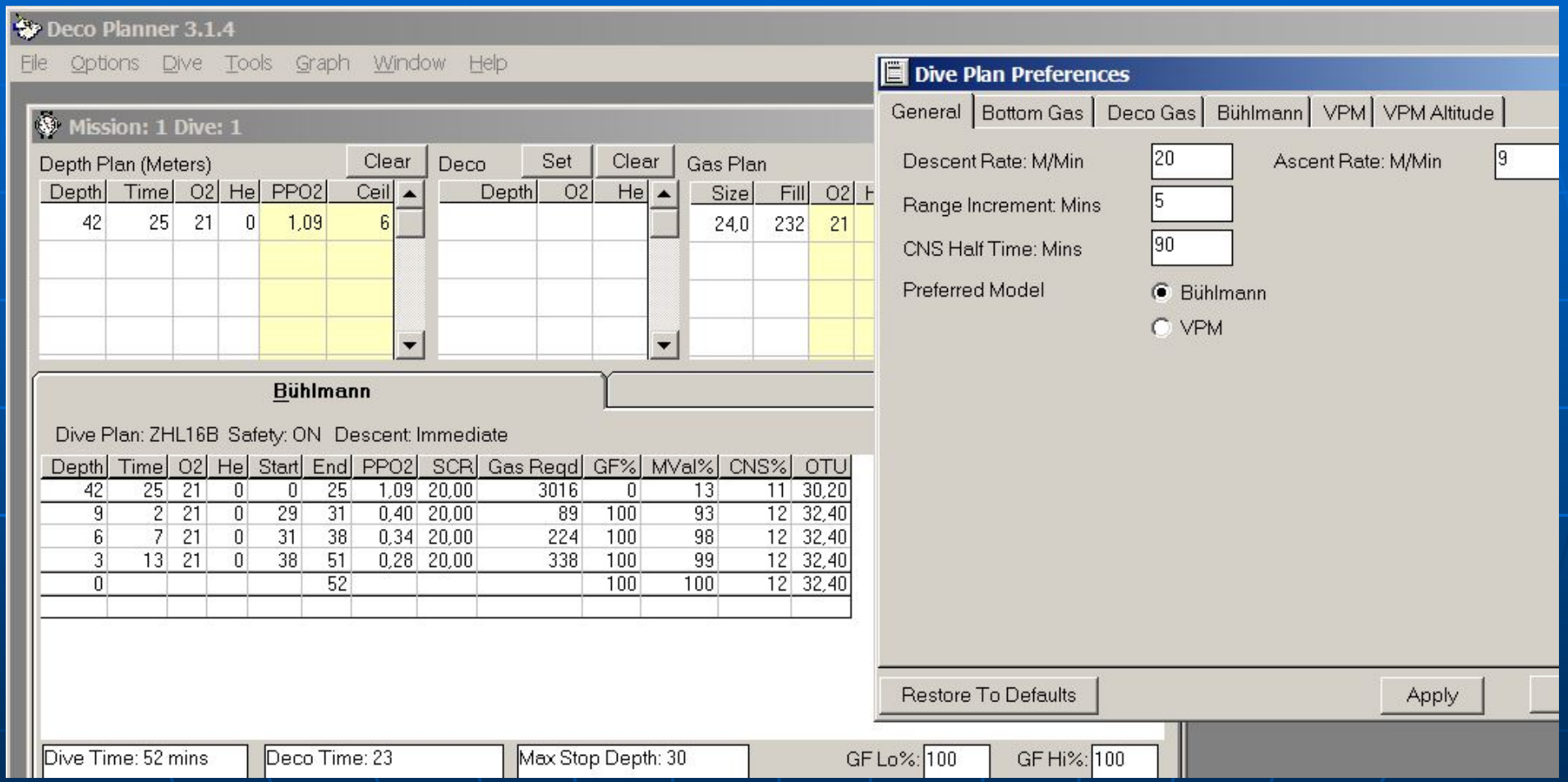

Test „Dive“: 42 m, 25 min, Air:

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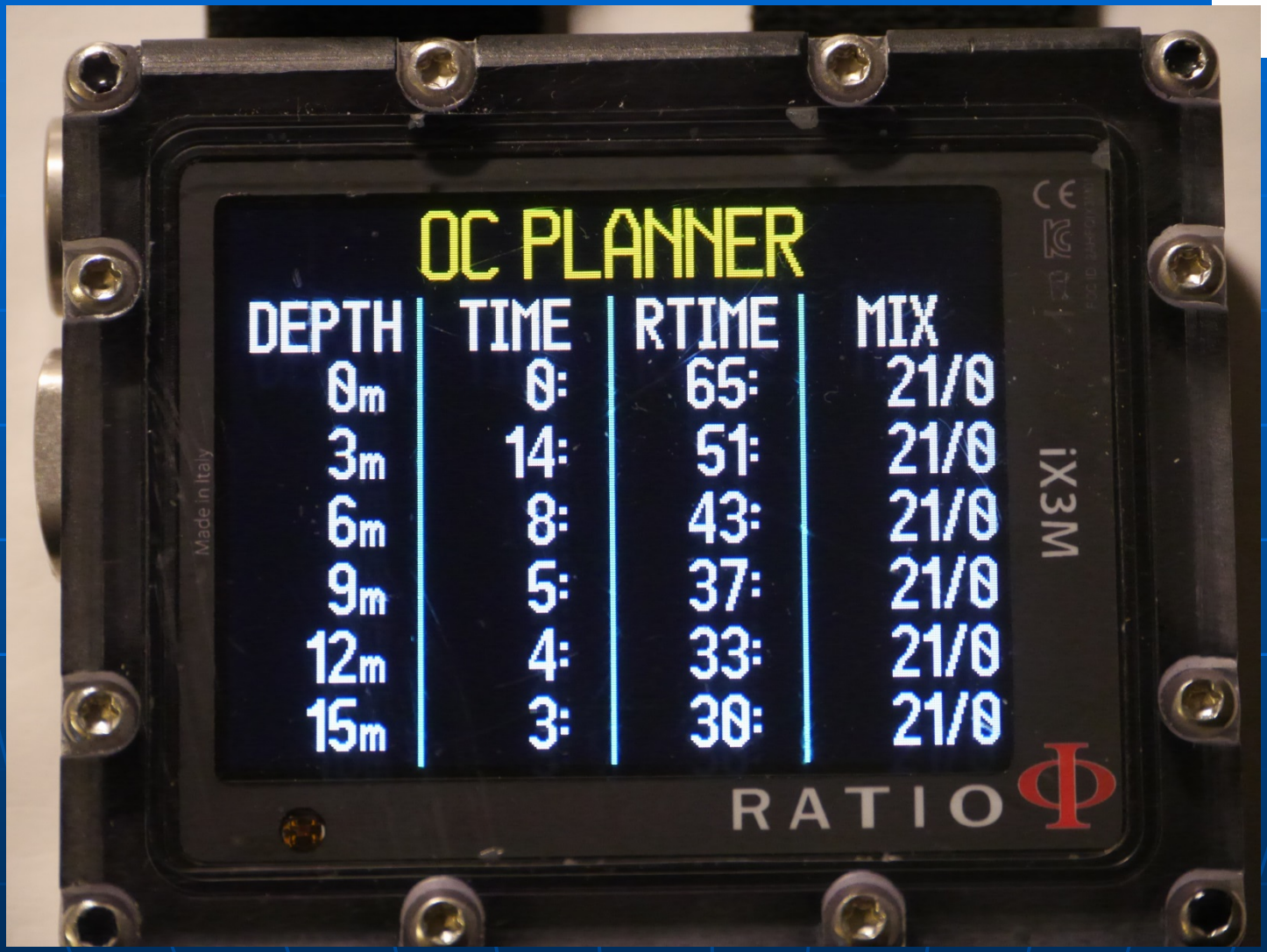

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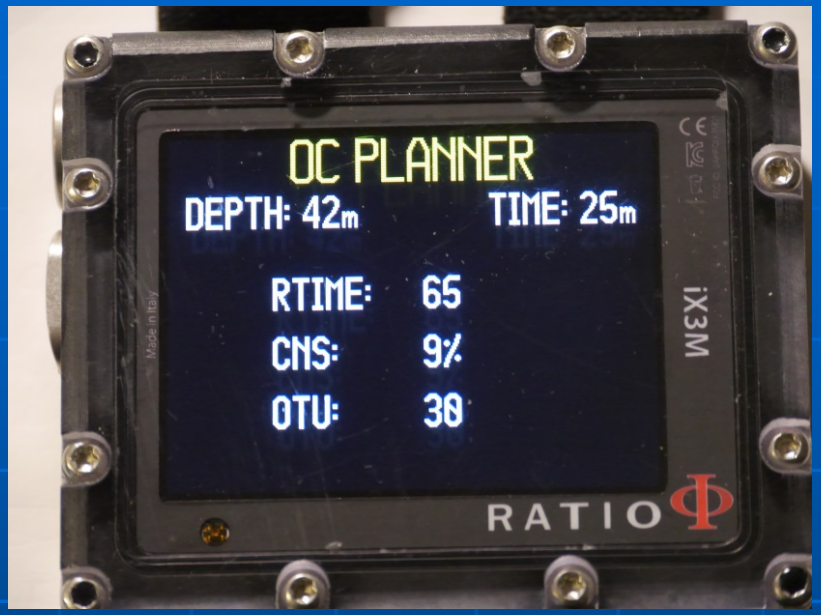

Conservatism:		deepest stop:
0 → decotime:	40’	18/2
1 →	69’	18/2
2 →	73’	18/3
3 →	81’	21/1
4 →	91’	21/2
5 →	108‘	21/3

Test „Dive“: 42 m, 25 min, Air:

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Info: RGBM Table from rgbmdiving.com
Bruce Wienke; 2003

depth = 140.00 fsw ppO2 = 1.10 atm
bottom time = 25. min OTU = 29. min CNS = 0.10 gas = 115. cft

stop	depth	wait	tissue	tension	grad	ppO2
1	60.00	0.00	1.67	94.91	46.79	0.59
2	50.00	1.00	1.67	85.29	46.79	0.53
3	40.00	2.00	3.33	73.17	43.83	0.46
4	30.00	2.50	3.33	62.52	43.83	0.40
5	20.00	3.00	3.33	53.82	43.83	0.34
6	10.00	7.00	6.67	40.04	40.44	0.27

total time = 45. min OTU = 29. min CNS = 0.11 gas = 134. cft

Test „Dive“: 42 m, 25 min, Air:

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Test „Dive“: 42 m, 25 min, Air:

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Info: USN
von Rev. 6: 2008→ Rev. 7: 12/2016

Table 9-9. *Air Decompression Table (Continued).*
(DESCENT RATE 75 FPM—ASCENT RATE 30 FPM)

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
140 FSW														
10	4:40	AIR									0	4:40	0	E
		AIR/O_2									**0**	4:40		
15	4:00	AIR									5	9:40	0.5	H
		AIR/O_2									**3**	7:40		
20	4:00	AIR									13	17:40	0.5	J
		AIR/O_2									**7**	11:40		
In-Water Air/O_2 Decompression or SurDO_2 Recommended ----------														
25	3:40	AIR								**3**	24	31:20	1	L
		AIR/O_2								**2**	**12**	18:20		
30	3:40	AIR								7	37	48:20	1	N
		AIR/O_2								**4**	**19**	27:20		

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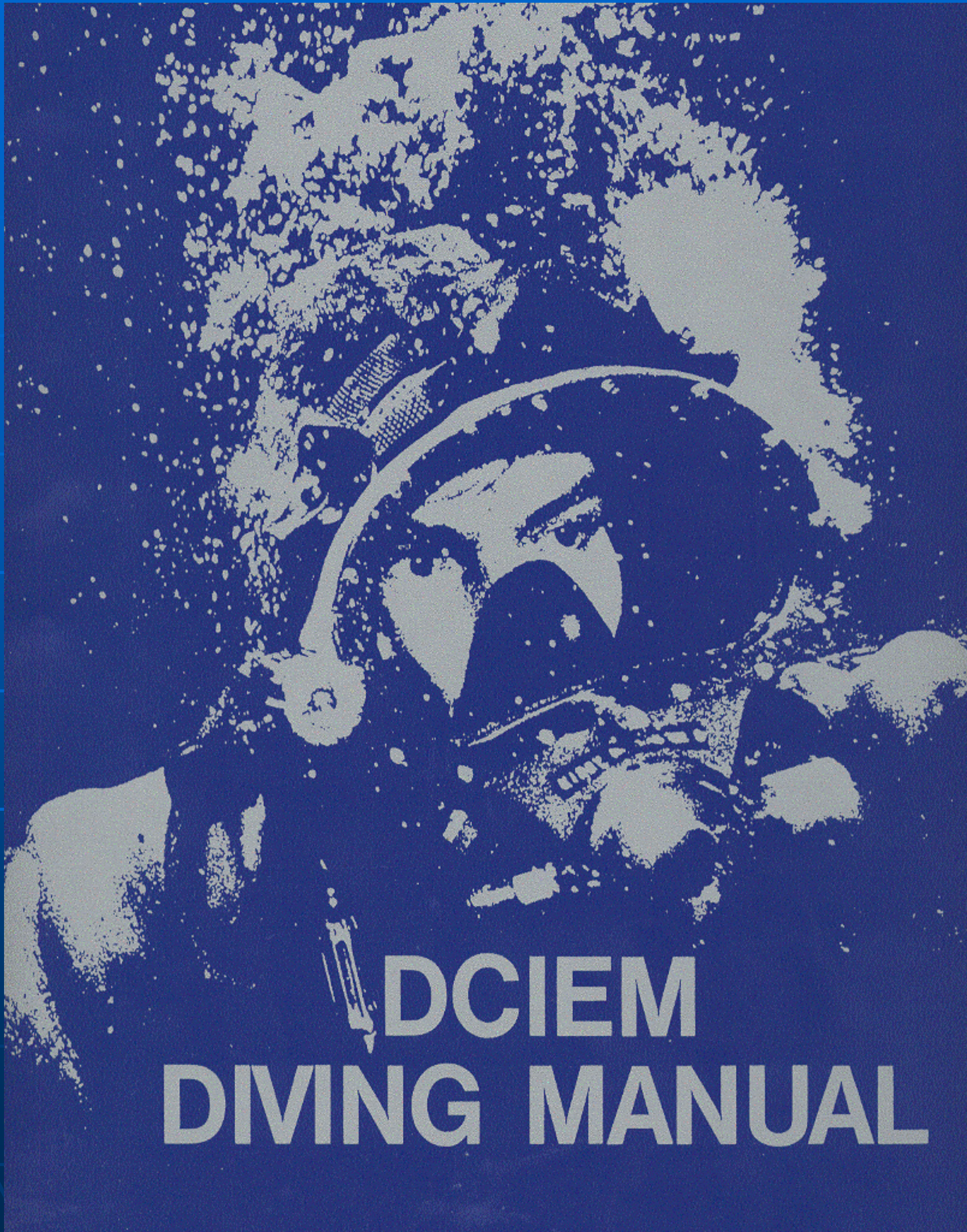

The Department of National Defence (Canada), Defence and Civil Institute of Environmental Medicine (DCIEM), and Universal Dive Techtronics, Inc. (UDT) disclaim any and all responsibilities for the use of these tables and procedures.

Test „Dive“: 42 m, 25 min, Air:

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Info: DCIEM
Kidd-Stubbs 1983

42	20	-	-	-	-	-	4	7	10	21	G
	25	-	-	-	-	-	7	8	17	32	I
	30	-	-	-	-	4	6	8	28	46	K
	35	-	-	-	-	5	7	9	37	58	L
	40	-	-	-	-	7	7	10	46	70	N
	45	-	-	-	3	5	8	16	53	85	O
	50	-	-	-	4	6	8	21	62	101	

Test „Dive“: 42 m, 25 min, Air:

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Info: DECO 2000
Max Hahn

42						
7'	4					C
	7					D
	10				2	E
	13			1	5	E
	16			4	6	F
	19		2	4	10	F
	22		3	6	13	G
	25	1	4	8	16	G

42 m, 25 min, Air; Synopsis:

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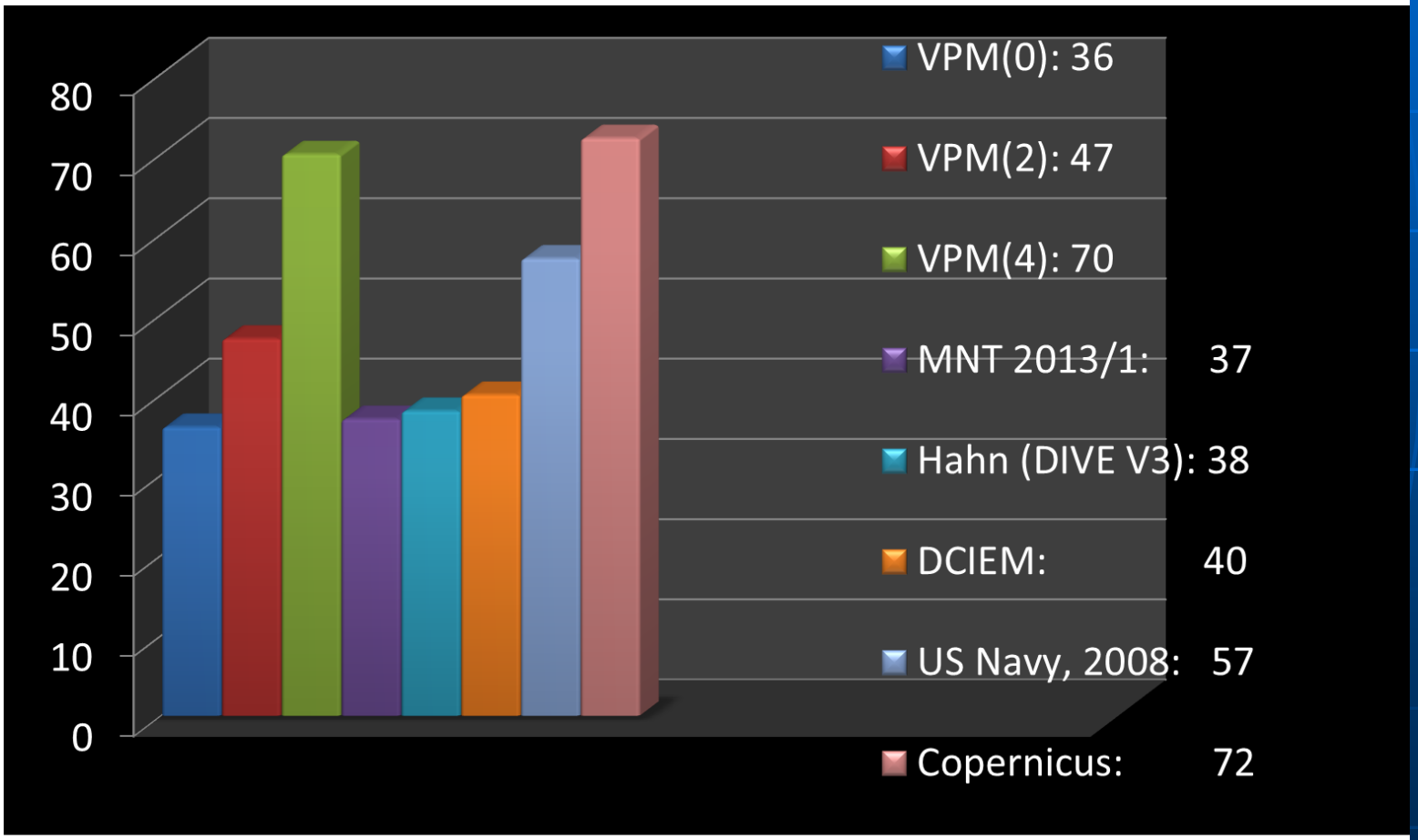
VPM	Name	Deepest stop [m]	TTS [min]	Variation
-	**RGBM**	15	**25**	n.a.
X	**Ratio**	18	**40**	40 – 108
X	**Excel**	21	**39**	n.a.
X	**SubS.**	21	**46**	46 - 72
X	**DP**	21	**47**	47 - 74

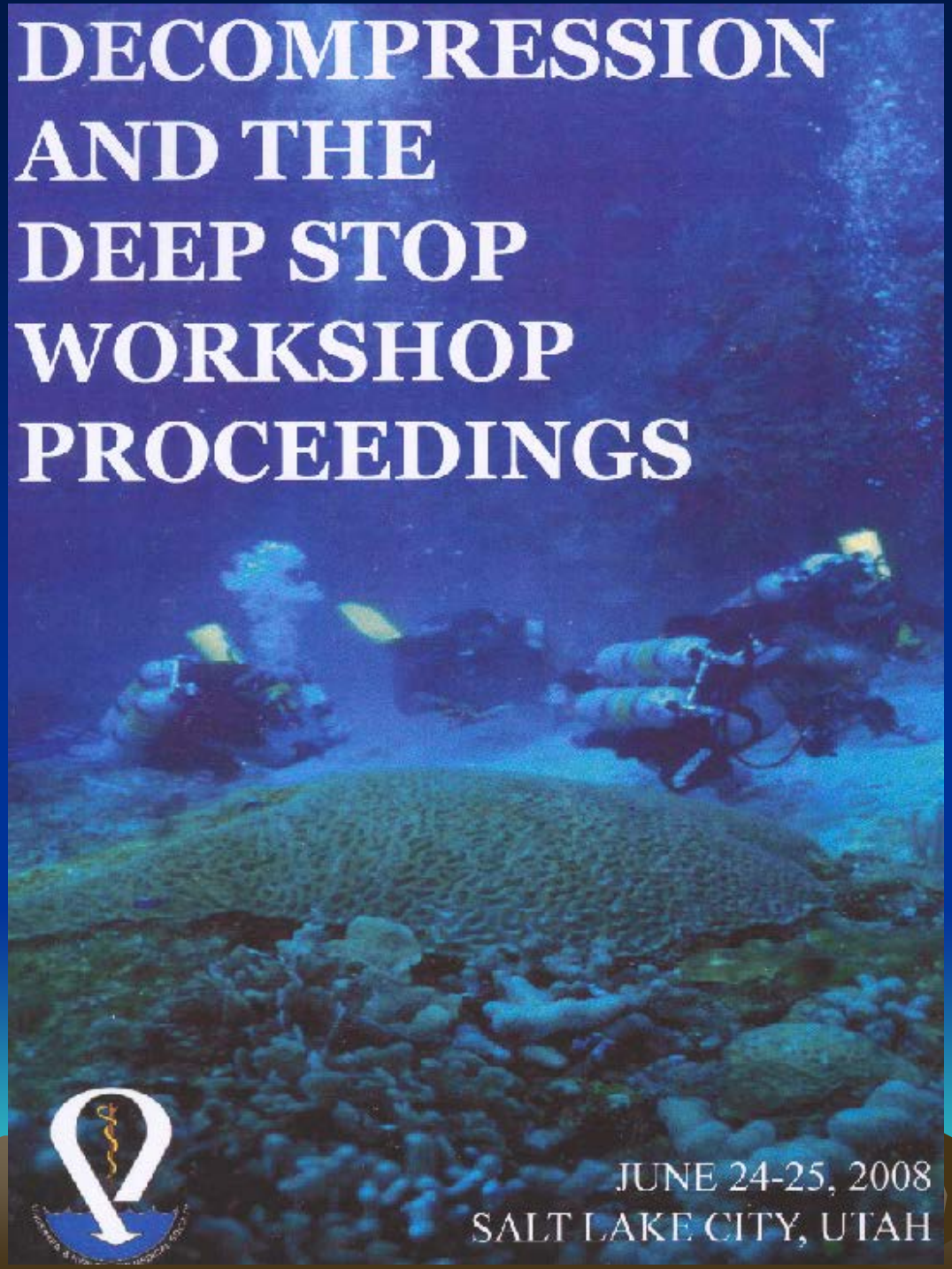
Per-fusion	Name	Deepest stop [m]	TTS [min]	
X	**Hahn**	12	**34**	
X	**DP**	9	**28**	
X / other	**USN/ DCIEM**	9	**32**	
X	**G2**	9	**39**	

Total decompression time + Ascent
Air dives → compared with VPM DP 3.1.4

TTS / min



24 msw (80ft) / 70 min


DECOMPRESSION
AND THE
DEEP STOP
WORKSHOP
PROCEEDINGS
JUNE 24-25, 2008
SALT LAKE CITY, UTAH


Touchsportcenter
Esslingen
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Workshop

PROCEEDINGS

DECOMPRESSION AND THE DEEP STOP

Salt Palace Convention Center
Salt Lake City, Utah, USA

JUNE 24-25, 2008

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Editors: Peter B. Bennett, Ph.D, D.Sc. Bruce Wienke, Ph.D, Simon Mitchell, MB, Ch.B., Ph.D

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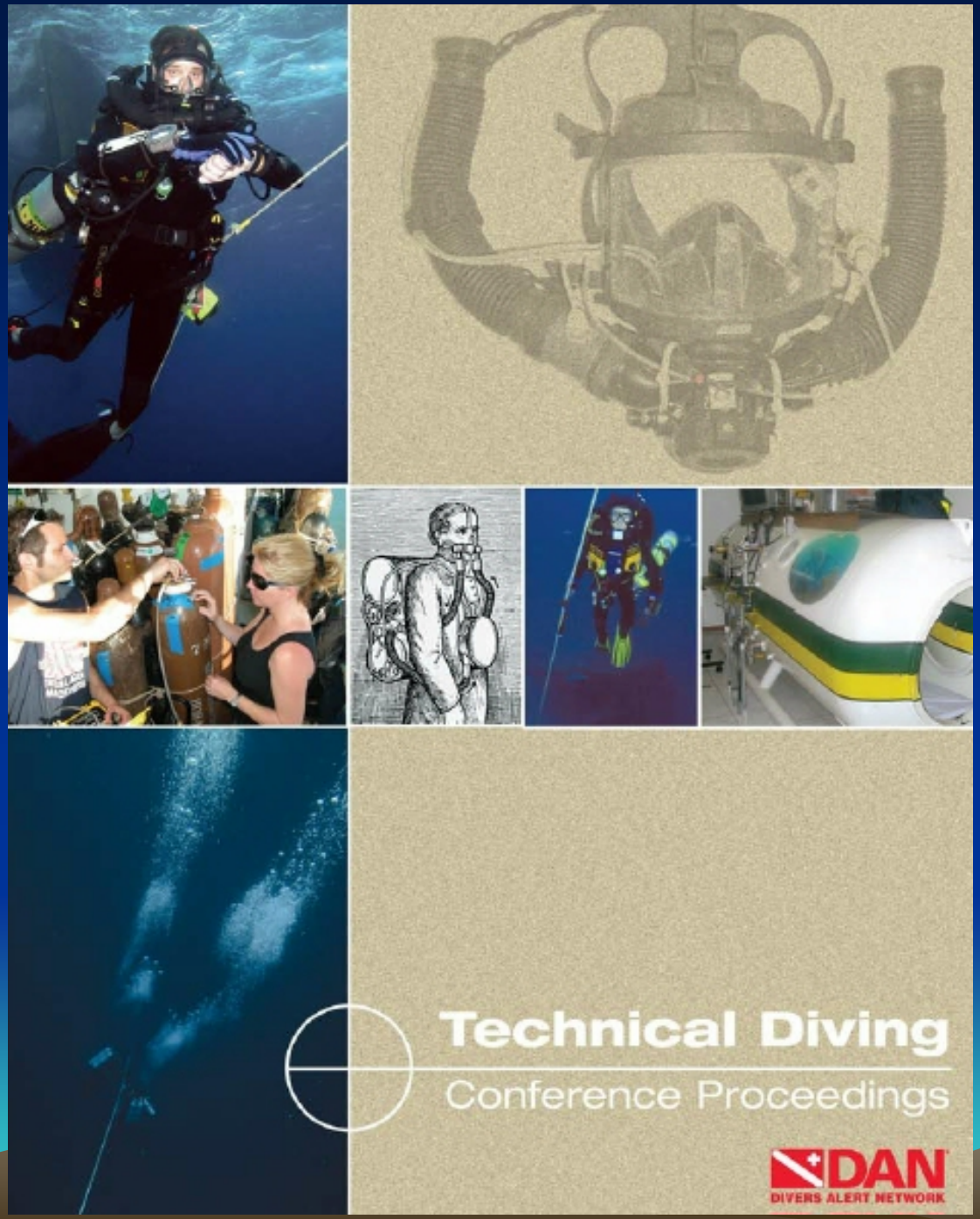
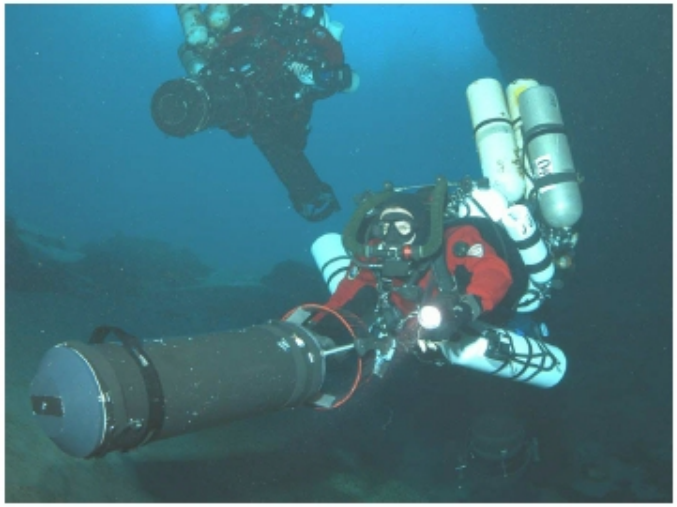




DAVID RHEA PHOTOGLUE.COM

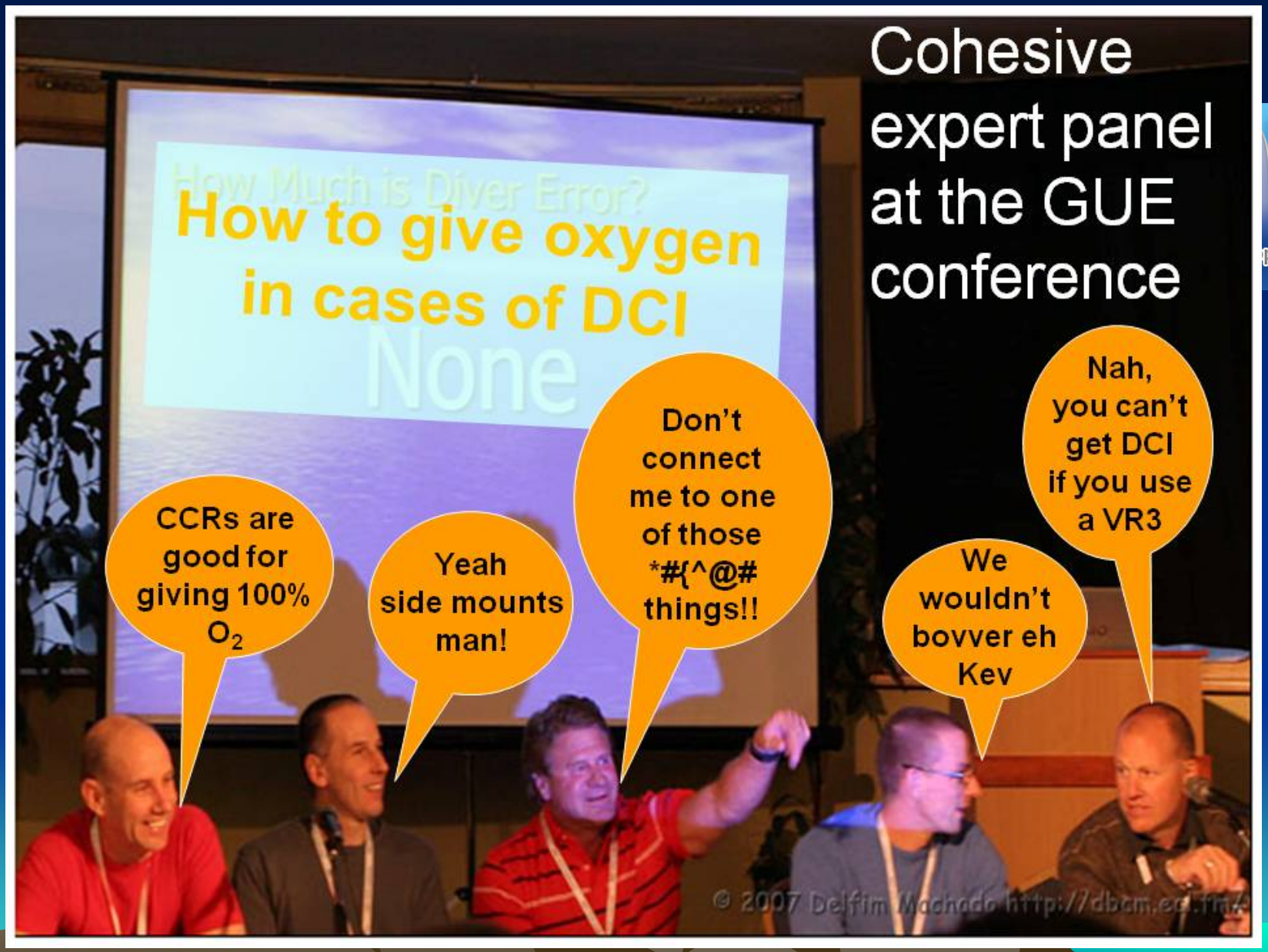
Technical Diving

Conference Proceedings

January 18-19, 2008

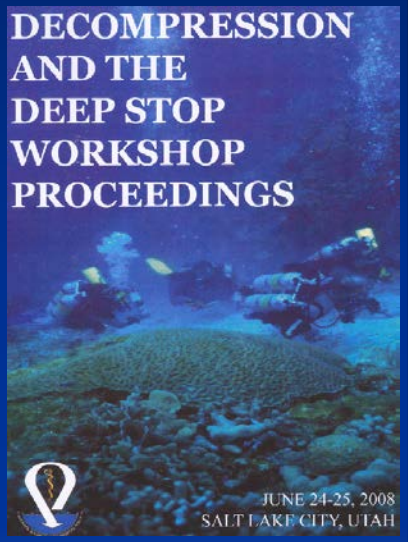
Richard D. Vann, B.A., B.S., Ph.D.
Simon J. Mitchell, M.B., Ch.B., Ph.D., DipDHM, FANZCA
Petar J. Denoble, M.D., D.Sc.
T. Gavin Anthony BSc, MSc, CChem, CSci, FRSC

The experts agree …



Source: DAN TEC 2008; Mitchell, Pyle, Moon

„Consensus Statement“ [100], p. 324:



Statement regarding the efficacy of „deep stops“ appropriate for release to the diving community:

„In respect of decompression diving there is conflicting evidence regarding the relative efficacy of decompression regimens that include empirical or model-derived deep stops (as defined) and decompression regimens prescribed by gas content models“

deco workshop @ Tauchsportcenter Esslingen

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Results from the USN / NEDU „deep stop“ study:

- → NEDU Report
- → Source: NEDU TR 11-06 July 2011
- → REDISTRIBUTION OF DECOMPRESSION STOP TIME FROM SHALLOW TO DEEP STOPS INCREASES INCIDENCE OF DECOMPRESSION SICKNESS IN AIR DECOMPRESSION DIVES. Navy Experimental Diving Unit, Authors: DAVID J. DOOLETTE, WAYNE A. GERTH, KEITH A. GAULT.

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→ 81 Navy divers
→ 192 dives / # DCS = 3 with the shallow stops
→ according to USN- VVAL18 (A1, „shallow“)

→ 198 dives / # DCS = 10 with “deep stops”
→ according BubbleVolumeModel(3) (A2, „deep“)

→ 170 feet (ca. 52 m) / 30 min bottom time
→ workload ca. 130 W, O_2-consumption ca. 2,3 L/min
→ ascent- & descent rates and water temperature meticously controlled!
→ TST (time-to-surface) = constant for both profiles = 174 min

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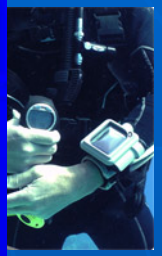
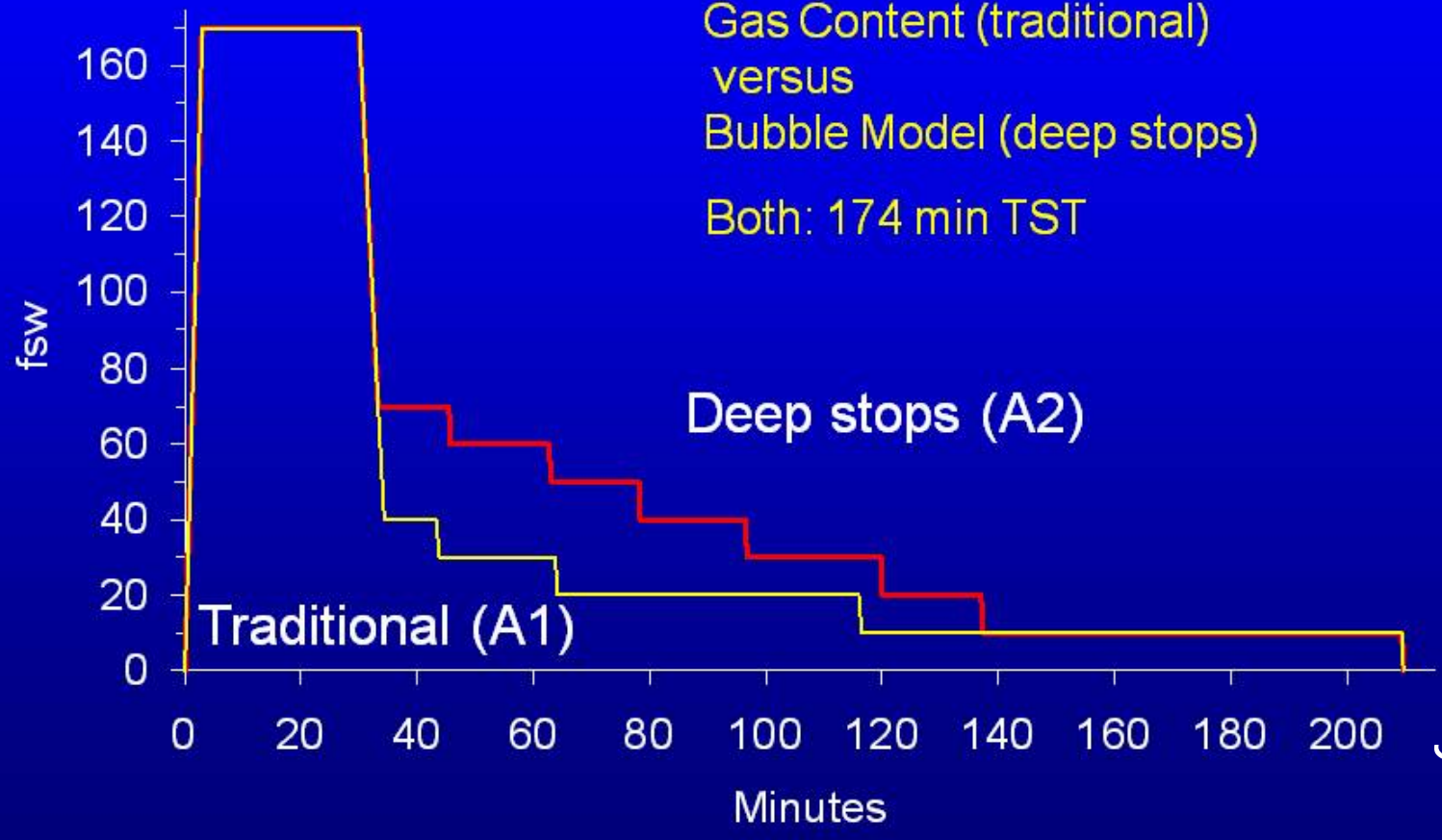
→ Source: NEDU TR 11-06 July 2011

depth / time	[feet]	[min.]						P (DCS)	[%]
stops:	70	60	50	40	30	20	10	BVM(3)	NMRI98
shallow (A1)				9	20	52	93	6,158	4,429
deep (A2)	12	17	15	18	23	17	72	3,664	5,880

NAVSEA
NAVAL SEA SYSTEMS COMMAND
Navy Experimental Diving Unit

Test Dive Profiles: 170 fsw/ 30 Min Air Dives





Source: NEDU TR 11-06 July 2011

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Source: NEDU TR 11-06 July 2011

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→ Source: NEDU TR 11-06 July 2011

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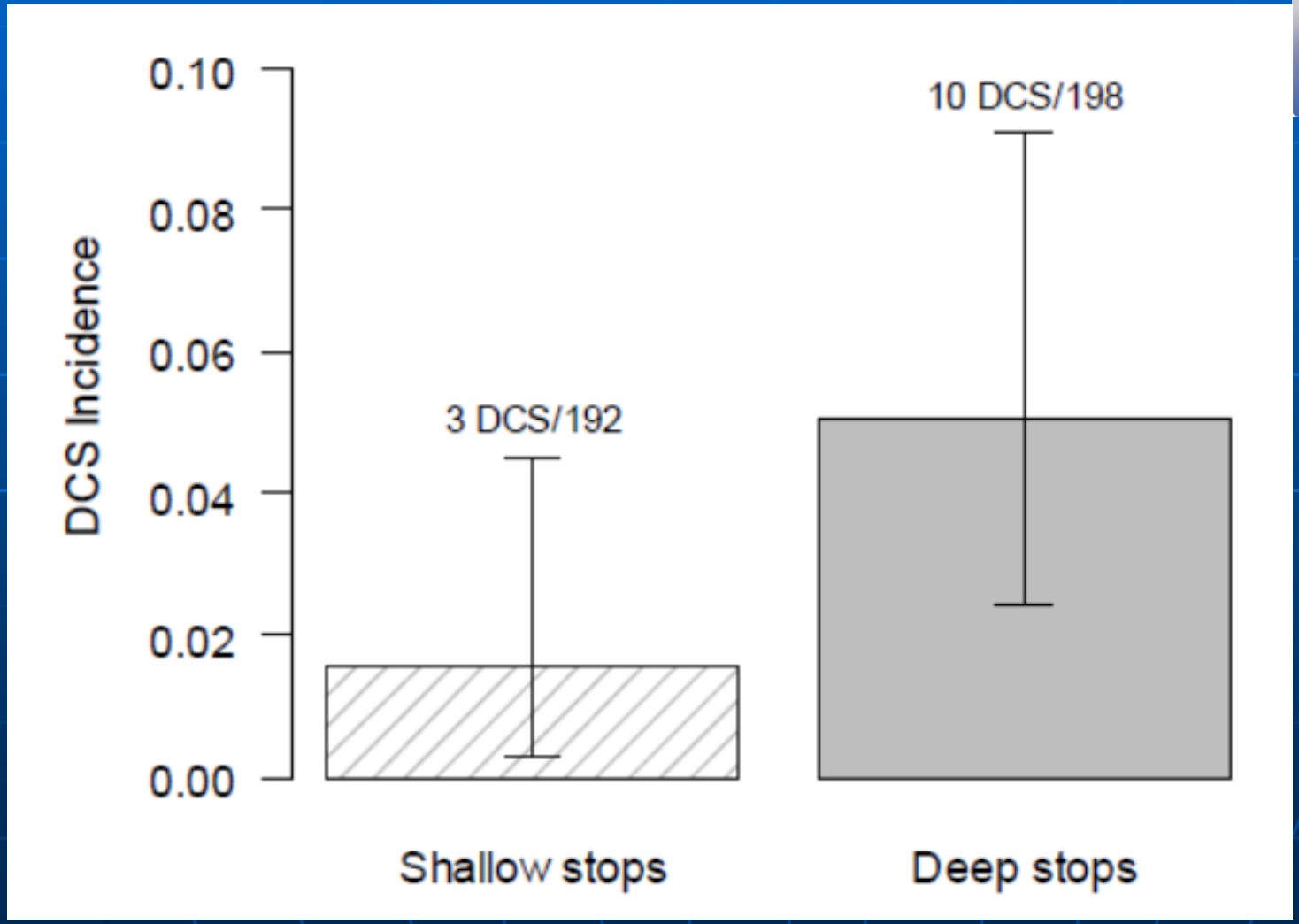

deco workshop @ Tauchsportcenter Esslingen

→ Source: NEDU TR 11-06 July 2011

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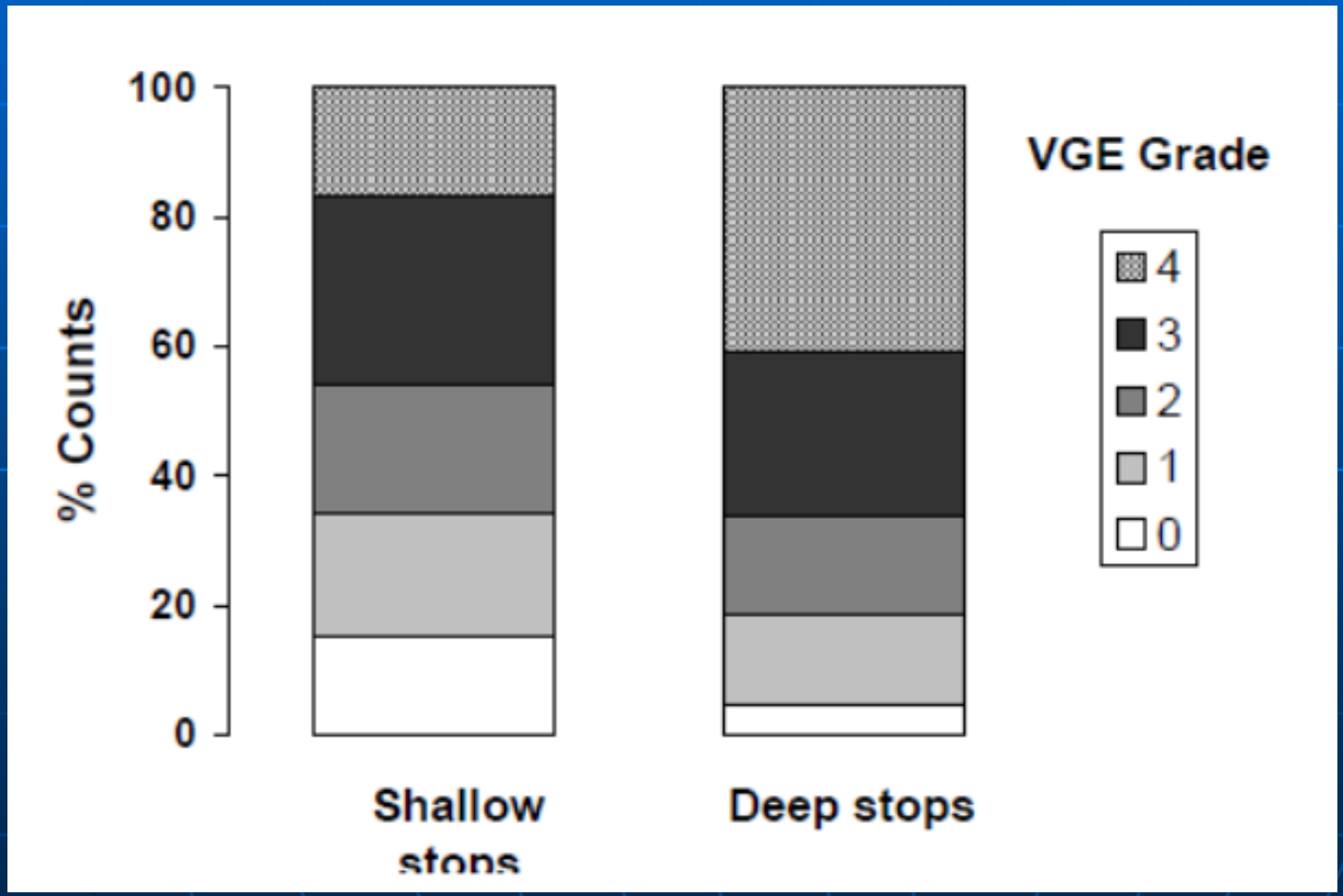

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→ Source: NEDU TR 11-06 July 2011

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CONCLUSIONS

The practical conclusion of this study is that controlling bubble formation in fast compartments with deep stops is unwarranted for air decompression dives.

Decompression controversies

Simon Mitchell
MB ChB, PhD, FUHM, FANZCA

Head of Department
Department of Anaesthesiology
University of Auckland

South Africa
October 2015

Thanks to Dr David Doolette

HE UNIVERSITY
OF AUCKLAND
FACULTY OF MEDICAL
/ 45:42

YouTube DE

decompression controversies

Conclusions

- "Optimal" decompression from deep bounce dives is unknown
- Approaches that emphasise deep stops are not supported by available data and have probably been 'oversold' to the technical diving community
- Best evidence suggests we should de-emphasise deep stops, but it remains uncertain by how much!

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P(DCS): statistical probability (P) of contracting a decompression sickness (DCS)

P(DCS) = 1.0 – P(no DCS)

P(DCS): dose- / response curve according to Hill

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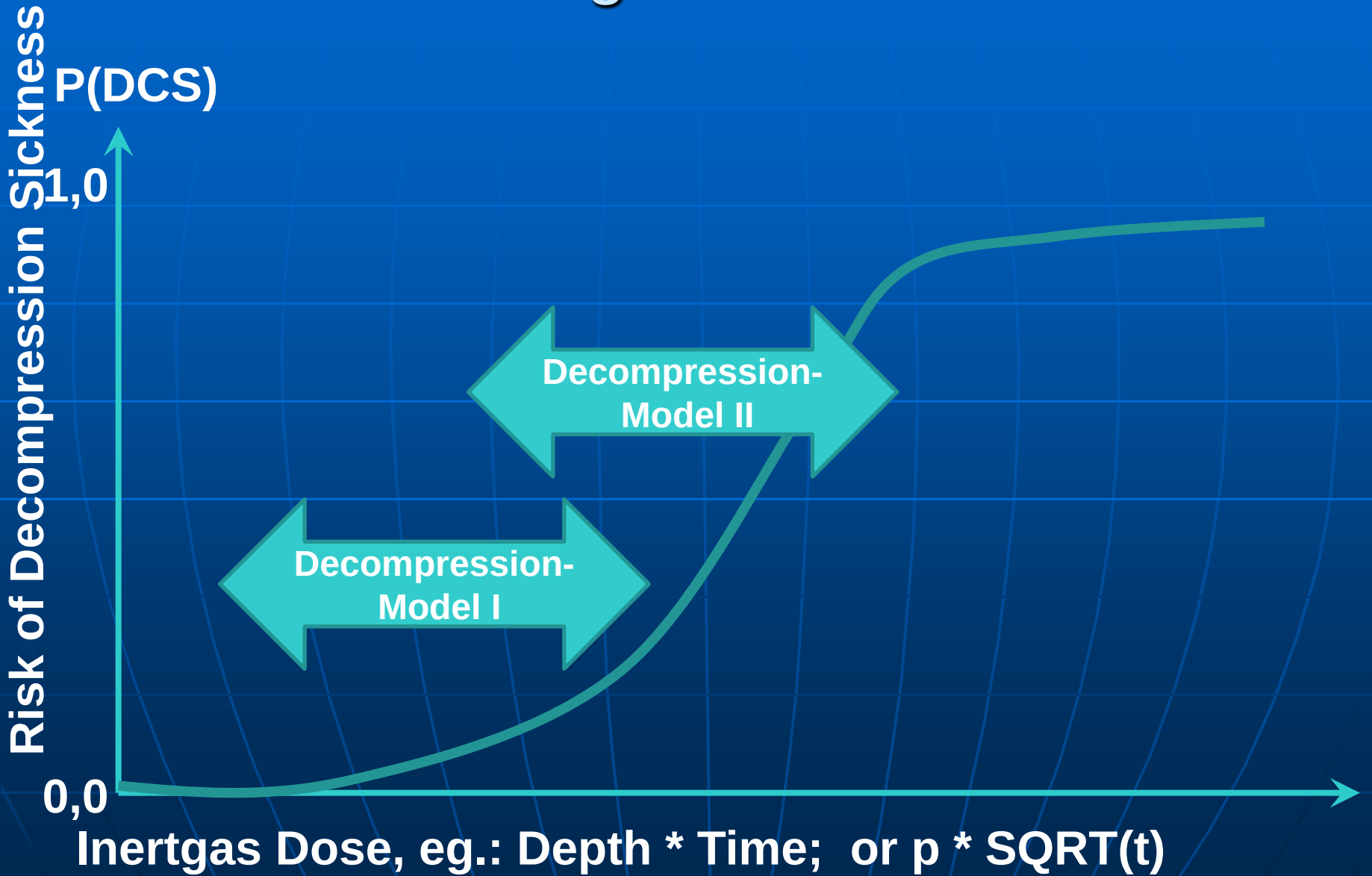

Source @ DAN:

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Costantino Balestra
Peter Germonpré

The Science of Diving

Things your instructor never told you

LAP LAMBERT Academic Publishing

The editors and authors of this book are a cadre of scientists and physicians with broad experience and knowledge of diving physiology and decompression theory. As is often the case, it requires a group effort to succeed in advancing practical knowledge. The colloquialism "the whole is greater than the sum of its parts" is often true and the PHYPODE Research Group epitomizes this concept. By logically grouping the various elements of diving science and medicine with provocative "food for thought" sections the text offers valuable lessons to those interested in the current state of diving. Despite nearly 170 years of research, the fundamental nature of decompression stress remains elusive. As is well outlined in this book, great advances have been made to the practical elements allowing for safe diving. Nonetheless, there are glaring voids of knowledge related to the nature of bubble nucleation, its consequences and methods to ameliorate risk. The synergy exhibited in this text not only provides a foundation for what is known, it offers a glimpse of where research is taking us. --- Professor Stephen R. Thom, Dept. of Emergency Medicine, University of Maryland School of Medicine

Editors: Costantino Balestra - Full-time Professor & Head of the Integrative Physiology Lab at the Haute Ecole Paul Henri Spaak; and Peter Germonpré - Medical Director of the Centre for Hyperbaric Oxygen Therapy of the Military Hospital Brussels, Belgium. Co-editors: M. Rozloznik, P. Buzzacott, D. Madden. European Underwater and Baromedical Society.

978-3-659-66233-1

DAN DSG data bank

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The Science of Diving – Things your instructor never told you …

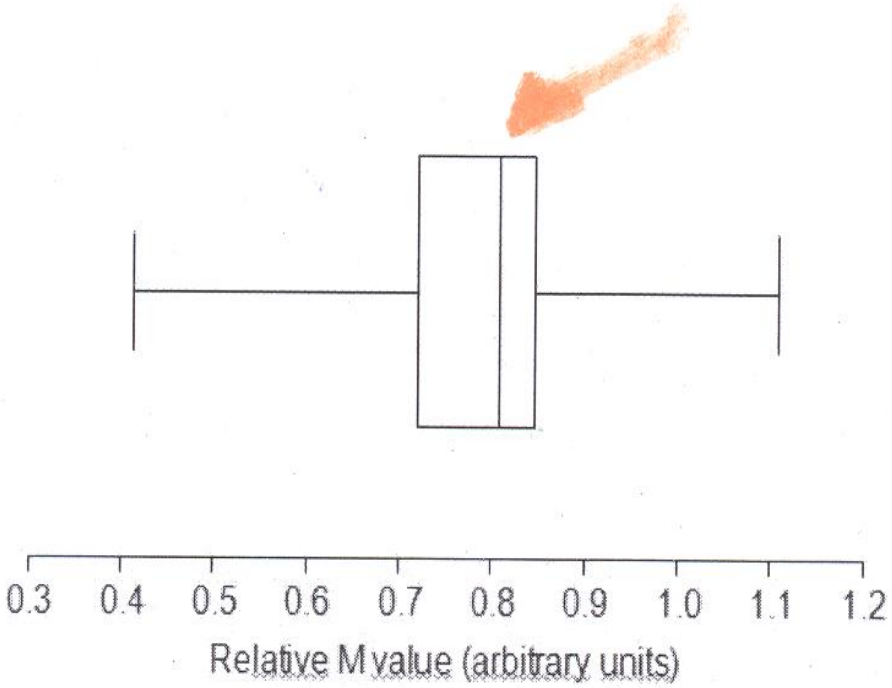

Figure 7: Box-plot of calculated tissue supersaturation levels on 165 cases of DCS recorded over 10738 DSL dives.

DAN DSG data bank

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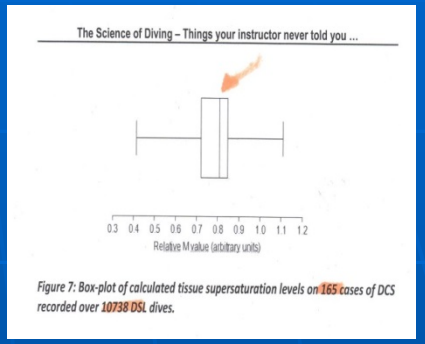
DSG (Diver Safety Guardian):
until 03/2015: 10,738 uploaded dive profiles
with 165 DCS cases,
unspecified, rate of 1.58 %;



→ DL 7 level 3 dive computer logs @ DAN DSG Portal.

→ Distribution of DCS cases:
ZH-L computers : RGBM
ca. 50 : 50

Hardly ever any compartment supersaturation!
The calculated saturations avg. < 80 % of allowed M-Values (source: lc. p. 29):

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„BIG DIVE DATA“

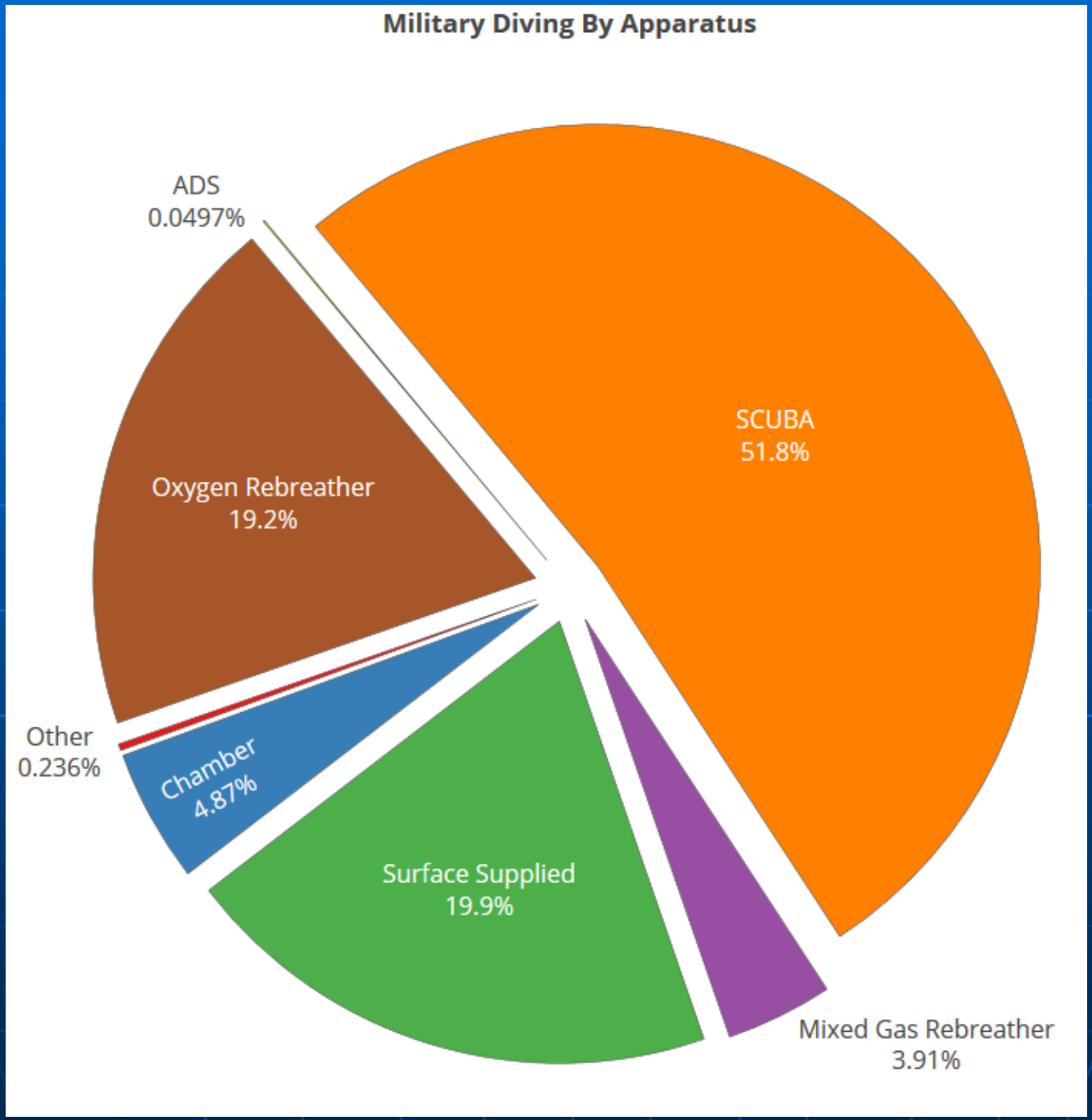
Source: http://divingresearch.scripts.mit.edu/militarydivingdata/

DIVE INTO DATA.

In 2008 the US military transitioned to a central, electronic dive logging system called the Dive Jump Reporting System, DJRS. Meant to increase visibility on diving trends and maintain an accessible system to view dive currency, the system has been a great asset to the dive community and its leadership.

In the summer of 2015, I requested the largest data draw in DJRS history: every electronic dive log and dive related mishap since DJRS implementation. Following a Freedom of Information Act request, the Naval Safety Center, owner and maintainer of the system, provided 768,851 dive log entries and 39 mishap reports (since 2008). In addition to the DJRS data, Atmospheric Dive Suit (ADS) dive logs were collected from the Portsmouth Naval Shipyard to further strengthen the dataset. Saturation Dive logs, however, were not obtained. With six years' worth of military dive history, we can quantitatively learn a lot about our community.

Figure 1 is a traditional histogram showing all military dives since 2008. All services, types of diving rigs, and tasks are represented. Some technical notes: (1) dives are broken into incremented 10 foot "bins," starting from the left limit; (2) The blue columns represent the total number of dives on a logarithmic scale; and (3) The orange line represents the cumulative percentage (Empirical Cumulative Distribution Function, ECDF) of dives achieved to a given depth.



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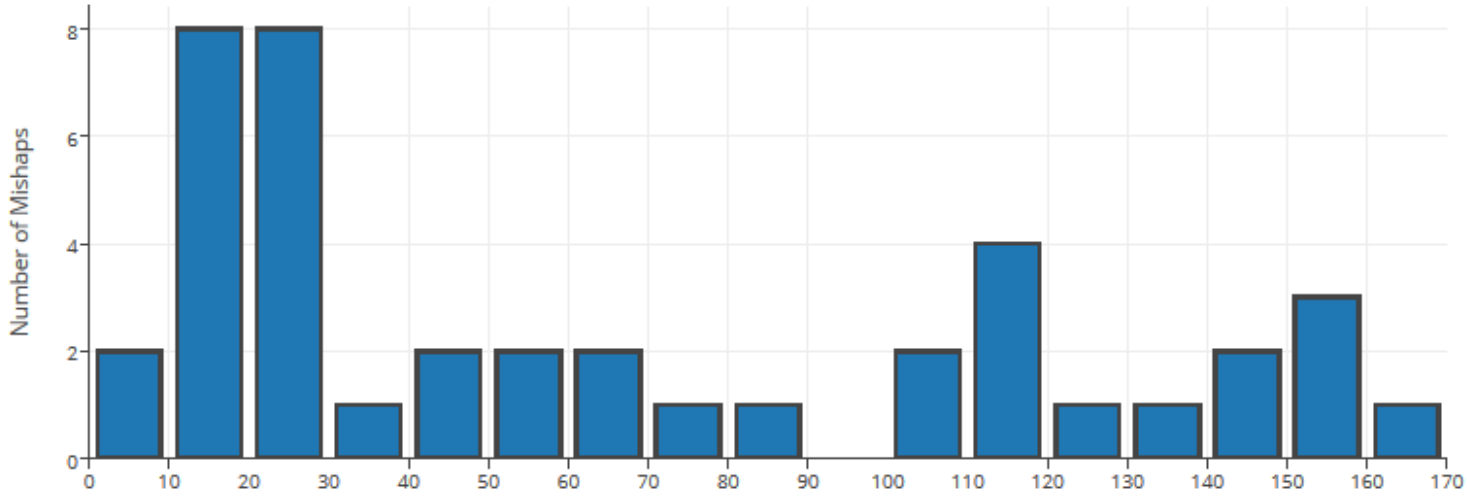
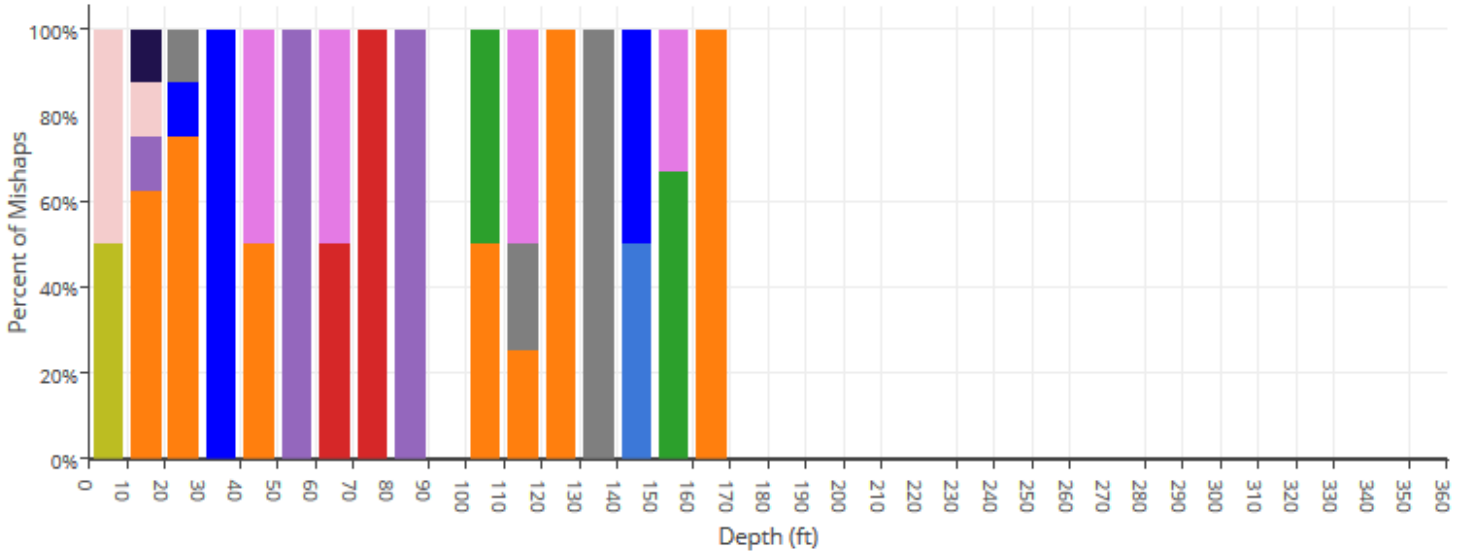
→ Deeper than ca. 145 feet (44 m):

→ mainly „mixed gas rebreathers“ & „surface supplied“

→ Deeper than 215 feet (65 m):
no more SCUBA!

Diving Related Mishaps by Casualty Type since 2008





- Total
- RETINAL EDEMA
- POIS
- NEAR DROWNING
- MISSED DECOMPRESSION
- HYPERCAPNIA
- DROWNING
- DCS II
- DCS I
- CHEM/TOXIC EXPOSURE
- BAROTRAUMA
- ARTERIAL GAS EMBOLISM

EDIT CHART

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„**BIG DIVE DATA**“:

→ only 41 „mishaps“,
with:

➔ DCS Type I + II: 3
➔ AGE: 18
➔ missed deco: 5

➔ all 3 categories
➔ DCI: 26 / 768.851 = < 0,04 % !!!

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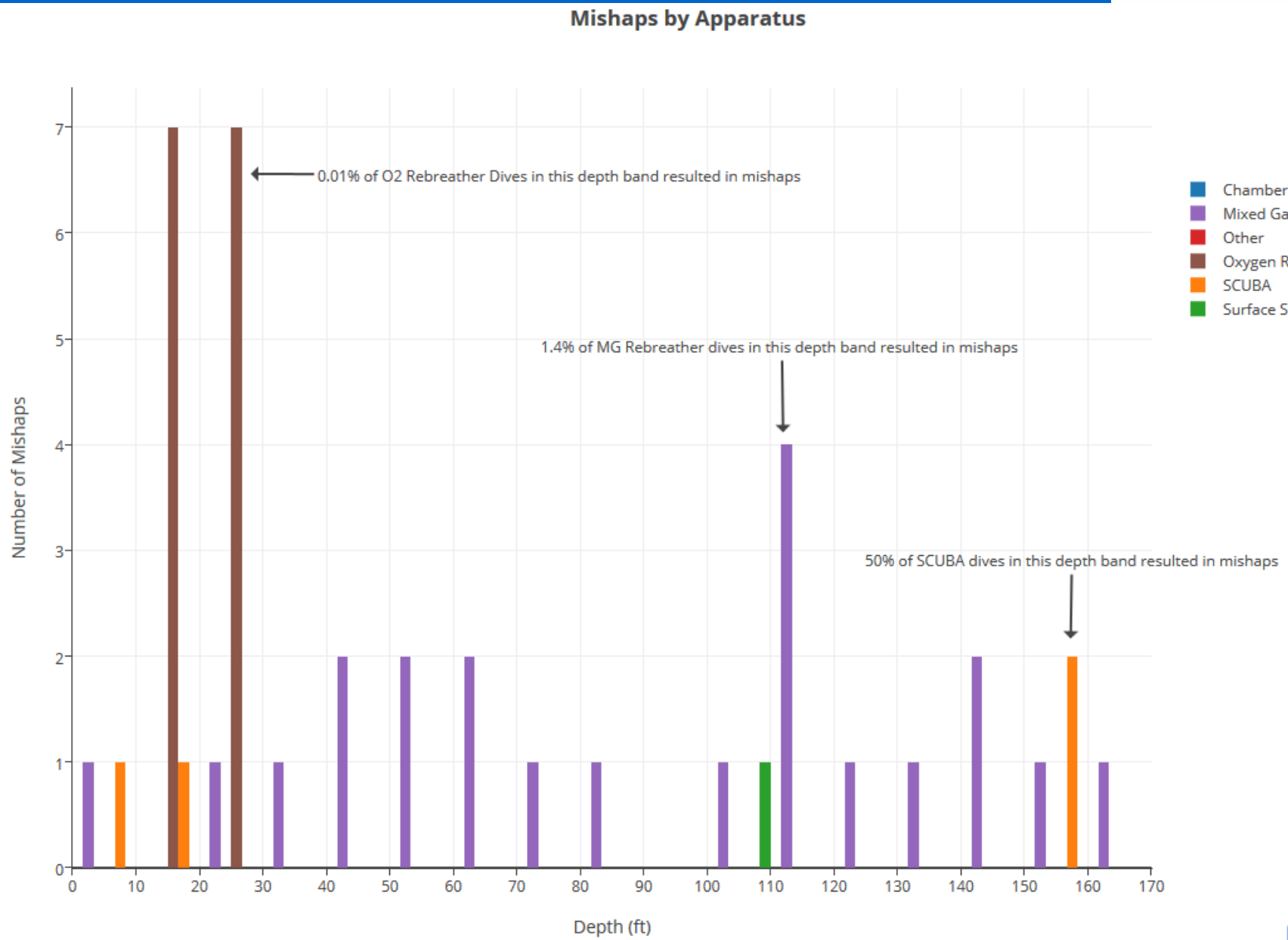

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„**BIG DIVE DATA**“: Summary / safety @ diving:

→ dive logs + Cochran® log-files USN
→ analysis of ca. 0.8 million dives
→ from 2008 until 2014
→ Average ca. 115,241 dives p.a.
→ only (ca.) **41 „mishaps“**

➔ 90 % of all dives < 60 feet
➔ 60 % of all dives < 20 feet
➔ Average depth 27.8 feet (= 8.5 m)

Take home (1st. lecture):

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- → VPM is a MODEL
- → not better or worse than any other
- → many simplifications
- → 5 free parameters
- → fit through traditional diving tables
- → many different implementations

- → Which one is “true”?
- → ALL AD HOC
- → NONE Tested
- → Don’t use a single source!

Take home (2nd. lecture):

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→ **Dive Computers & Desktop Deco Software**
→ **may have bugs!**

(“may” means: they HAVE bugs!!!)

→ **There are no consensus standards on:**

→ **<u>Implementation & Parameters</u>**
→ **as well <u>no documentation or public quality control</u>!**

→ **<u>Do not rely on a single source!</u>**
→ **Use multiple products!**
→ **Compare!**
→ **Do not fall prey to the (not-) RTFM-Error !!!**
→ **(Go & buy & use a portable doppler unit!)**

Cave: Dive Computers!

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WARNING

This computer has bugs. Although we haven't found them all yet, they are there. It is certain that there are things that this computer d s that er we didn't think about, or planned for it to do something different. N ur life on only one source of information. Use a second computer or s. d choose to make riskier dives, obtain the proper training and work th owly to gain experience.

This computer will fail. It is whet t will fail but when it will fail. Do not depend on it. Always have a plan ow t ndle failures. Automatic systems are no substitute for knowledge and t ing

No technology will keep you alive. Knowledge, skill, and practiced procedures are your

best defense. (Except for not doing the dive, of course.)

Take home:

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Take home:

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Downloads:

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→ „all“ VPM (& RGBM …) papers:
https://www.divetable.info/area.htm#Kap%207

→ 6 Copernicus papers:
https://www.divetable.info/TEMP/CSD_2018/Copernicus.zip

→ DAN TEC Conference 2008:
https://www.divetable.info/TEMP/CSD_2018/Proceedings.pdf

→ USN, only tables 2008 / 2016:
https://www.divetable.info/workshop/USN_Rev7_Tables.pdf