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TWENTY-FIRST CENTURY SURFACE-SUPPLIED HELIOX DECOMPRESSION TABLE DEVELOPMENT

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14. ABSTRACT
The Surface-Supplied Helium-Oxygen (SS He-O_2) Decompression Table in the current *U.S. Navy Diving Manual* (Revision 7, Change A) is an edited version of an original 1939 issue with a limited record of success in operational dives to depths of 240 feet sea water (fsw) or shallower. Recent theoretical evaluations indicate that schedules in this table for longer and deeper dives that are increasingly within the scope of desired U.S. Navy diving operations but have a limited history of use will incur unacceptably high risks of decompression sickness (DCS). Navy Experimental Diving Unit (NEDU) generated three tables of SS He-O_2 decompression schedules to incur a 2.3% maximum estimated risk of DCS over operationally useful ranges of dive depth and bottom time and be considered as candidates to replace the current U.S. Navy SS He-O_2 Decompression Table. One table was generated with a three-region unstirred tissue (3RUT) gas and bubble dynamics probabilistic model fitted to the he8n25 dataset used to produce the 1.3 atm oxygen partial pressure in helium tables in the current *U.S. Navy Diving Manual*. Numerical difficulties and inordinately long computation times required to solve the model equations for a given He-O_2 dive thwarted more advanced applications of the 3RUT model to SS He-O_2 diving. The two other tables were generated with an updated linear-exponential multi-gas (LEM) probabilistic model fit to a larger N2He_2016 dataset expanded to include more constant oxygen fraction He-O_2 dives representative of SS He-O_2 diving. The second of these tables included a modification to accommodate a ±0.5% gas mixing error allowed in the *U.S. Navy Diving Manua*l. After comparisons of the candidate SS He-O_2 tables and the current MK 16 MOD 1 He-O_2 decompression table, the latter table is recommended as the best candidate to replace the current U.S. Navy SS He-O_2 decompression table. Man-testing of representative schedules in the recommended replacement table completed to confirm that the schedules incur acceptable risks of DCS is described in a follow-on report.

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surface-supplied diving, heliox, decompression sickness, decompression table, probabilistic modeling

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INTRODUCTION

Air and other nitrogen-oxygen (nitrox) breathing mixtures are impractical for deep diving because gas mixtures with high nitrogen partial pressures are narcotic and dense, which result in mental impairment and increased work of breathing. Instead, mixtures of helium and oxygen ("heliox" or "He-O_2") are usually breathed during dives deeper than 150 feet sea water (fsw) because helium is not narcotic and is less dense than nitrogen. The current *U.S. Navy Diving Manual*[1] contains procedures for heliox saturation diving, where divers live and work for days or weeks at elevated pressure, and three sets of procedures for heliox bounce diving, where divers return to surface after each working bottom phase of only minutes or hours duration.

The first and oldest set of heliox bounce diving procedures supports operations in which divers are supplied with pre-mixed heliox gas from the surface through a flexible hose to a helmet and open-circuit regulator, and includes decompression schedules little changed from those first described by Momsen in 1939.[2] Decompression schedules in these surface-supplied heliox (SS He-O_2) procedures were calculated using the original Haldane algorithm with seven tissue gas exchange half-times ranging from 5 to 60 minutes, each with a maximum allowed tissue partial pressure of helium and water vapor of 1.7 times the ambient pressure. Shifts from bottom gas mix to 100% O_2 at 60 and 50 fsw in-water decompression stops were prescribed with direct ascent to surface after completion of the 50 fsw stop. Because the depth dependence of the inspired helium partial pressure in SS He-O_2 dives varies with the oxygen fraction in the bottom mix, schedules were tabulated as calculated for bottom times at each of a series of increasing helium partial pressures to maximize the applicability of schedules for a given partial pressure to the widest ranges of inspired O_2 fraction and dive depth. Although 700 man-dives were reportedly conducted during development of these schedules, none of these dives, including those resulting in decompression sickness (DCS), are described in the original report.[2] Selected schedules were tested in a later series of 134 chamber dives to depths from 75 to 429 fsw with 4 cases of DCS in dives to depths of 363 fsw or greater.[3]

In 1950, the in-water oxygen breathing stops in the 1939 tables were moved from 60 and 50 fsw to 50 and 40 fsw to reduce the incidence of oxygen toxicity. Times at these stops were re-calculated after addition of a 70-minute half-time compartment to those used to compute the original schedules.[4,5] Field use of these tables between 1960 and 1969 resulted in a low incidence of DCS, but the cases of DCS appeared to be overrepresented at depths deeper than 200 fsw.[6]

In 1970, an alternative set of surface-supplied heliox decompression schedules was computed[6] with ostensibly more conservative ascent criteria published by Workman[7] as a potential replacement for the 1950 tables. Testing of these schedules was discontinued because they resulted in a 16.7% incidence of DCS in tested in-water schedules and a 33% incidence in tested surface decompression schedules.[6] The 1950 tables for SS He-O_2 decompression were retained unchanged in the *U.S. Navy Diving Manual* with reported field use between 1970 and 1984 resulting in 11% DCS for dives to 200 fsw or deeper or for bottom times of 30 minutes or longer.[8]

The 1950 tables were modified empirically for issue in Revision 3 of the *U.S Navy Diving Manual* in 1991[9] in another attempt to reduce the risks of DCS. The separate partial pressure tables were reformatted and aggregated into a single table of Minimum/Maximum Percent Oxygen schedules grouped by dive depth according to 2% less than the minimum inspired oxygen percentage allowed at each depth.[a] Breathing of 60% He/40% O_2 at decompression stops from 100 to 60 fsw was introduced for decompressions from dive depths greater than 200 fsw. These modifications effectively reduced the incidence of DCS, but occasioned an unacceptable incidence of central nervous system (CNS) oxygen toxicity during in-water decompression stops.[8]

Further empirical modifications of the table were made in 1999 to reduce the risk of central nervous system oxygen toxicity. In-water 100% oxygen breathing was moved from the 50 fsw and 40 fsw stops to new 30 fsw and 20 fsw stops with times at the 50 fsw, 40 fsw, and shallow new stops assigned by rule based on the 60 fsw stop time. Additionally, shifts to 60% He/40% O_2 at 100 fsw during ascent from dives deeper than 200 fsw were removed, shifts to 50% He/50% O_2 at 90 fsw or at the first stop shallower than 90 fsw during ascent were added, and the ascent rate was reduced to 30 fsw/min.[8] Based on risks of DCS estimated for the revised schedules with the then recently developed LEM-he8n25 probabilistic model,[10] the revised table was used in surface-supplied heliox dives undertaken with surface decompression using oxygen (SurDO_2) in the summer months of 2000 to stabilize the sunken wreckage of the former USS Monitor for historical preservation and later recovery.[8] No CNS oxygen toxicity cases and only two DCS cases were reported in 148 dives completed on 200- to 240-fsw schedules (including 134 dives on 230 fsw schedules) with 30- to 40-minute bottom times in this series. On the basis of these results, the table was promulgated for fleet use with first appearance in the *U.S. Navy Diving Manual, Revision 4, Change A*, dated 1 March 2001.[11] This Surface Supplied Helium-Oxygen Decompression Table appears unchanged in the current *U.S. Navy Diving Manual*.[1] No formal laboratory tests of the schedules in this table have been conducted.

A set of heliox decompression schedules described by Workman and Reynolds[12] was published in the March 1970 edition of the *U.S. Navy Diving Manual*[13] for use with the MK 6 semi-closed-circuit self-contained underwater breathing apparatus (SCUBA) to depths up to 200 fsw.[b] The MK 6 underwater breathing apparatus (UBA) was ultimately replaced by electronically controlled closed-circuit underwater breathing apparatus (EC-UBA), which deliver constant oxygen partial pressure (PO_2) breathing gas to free-swimming divers at dive depths to greater than 300 fsw. The Workman schedules were replaced by the remaining two sets of current U.S. Navy heliox bounce diving decompression procedures developed to support EC-UBA dives with helium as the background inert gas. The first set of these procedures was developed to support constant 0.75 atm PO_2 heliox bounce diving with MK 16 MOD 0 EC-UBAs, and has appeared in the *U.S. Navy Diving Manual* since Revision 2 issued in October 1987.[14] The second and most recent set of these procedures was developed to support

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[a] While the maximum allowed bottom PO_2 was 1.30 atm at all dive depths in the new table, schedules in the table were based on those in the 1950 tables for bottom PO_2 ranging from only 0.40 to 1.00 atm.
[b] These were the "new" heliox decompression tables in the 1970 Diving Manual, not the Oxygen Partial Pressure Tables for Helium-Oxygen Decompression as erroneously stated in reference 8.

constant 1.3 atm PO_2 heliox bounce diving with the MK 16 MOD 1 EC-UBAs,[10] and has appeared in the *U.S. Navy Diving Manual* since Revision 5 issued in August 2005.[15] EC-UBAs are well-suited for heliox bounce dives in which only relatively light work must be performed, such as mine countermeasures dives. However, heliox bounce dives in which heavy work must be performed, such as salvage dives, are still best undertaken with surface supplied gas and open-circuit UBA because these typically have lower work of breathing than EC-UBAs.

The risks of DCS in surface-supplied heliox bounce dives to deeper than 240 fsw or for bottom times of 30 minutes or longer have attracted renewed interest as operations requiring such dives continue to occur.[16] At the outset of current work, the probabilistic model on which the present U.S. Navy MK16 MOD 1 1.3 atm PO_2-in-He decompression schedules are based (LEM-he8n25)[10] was the only tool available for estimation of DCS risks in heliox dives. This model had been shown to provide exaggerated estimates of risks of DCS for long deep dives in the present in-water Surface Supplied Helium Oxygen Decompression Table (Figure 1).[8] Navy Experimental Diving Unit (NEDU) was tasked to replace this table with a table of schedules computed with modern DCS modeling technology to incur more acceptable risks of DCS.[17] For example, a 2.0 – 2.3% acceptable risk of DCS was adopted for computation of the current U.S. Navy 1.3 atm PO_2-in-He decompression schedules.[10]

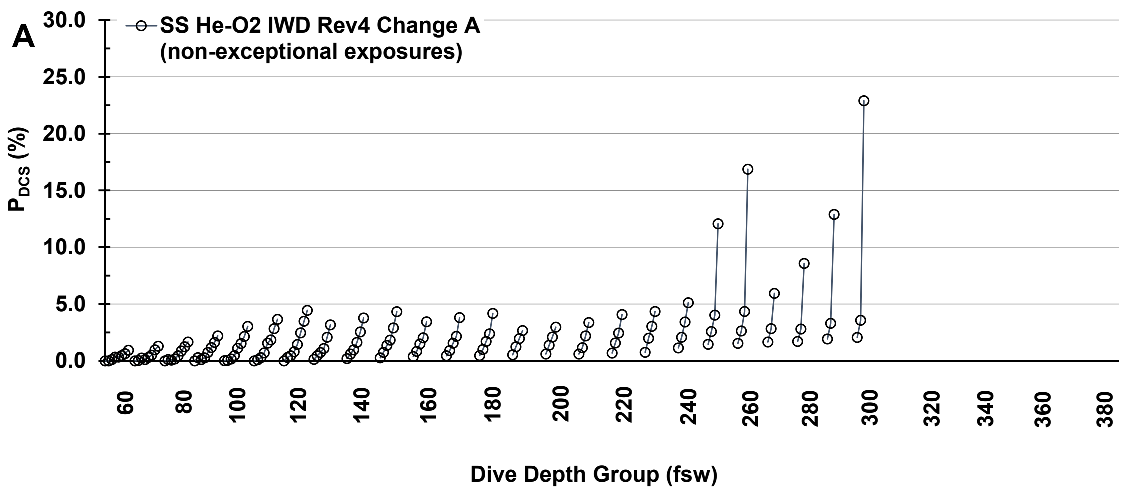

Figure 1-A. LEM-he8n25 model-estimated risks of DCS (P_{DCS}: probability of DCS)[c] for normal non-exceptional exposure in-water decompression schedules in the current U.S. Navy Surface-Supplied Helium-Oxygen Decompression Table. Risks were computed assuming that heliox with the maximum allowed oxygen fraction at each dive depth is breathed for an inspired PO_2 of 1.3 atm at each depth. Schedules, each represented by an open circle, are ordered by increasing bottom times in groups of increasing dive depth. Lines between points are shown for clarity only.

[c] Risk of DCS and probability of DCS (P_{DCS}) are synonyms. For compactness P_{DCS} is used in figure axis labels.

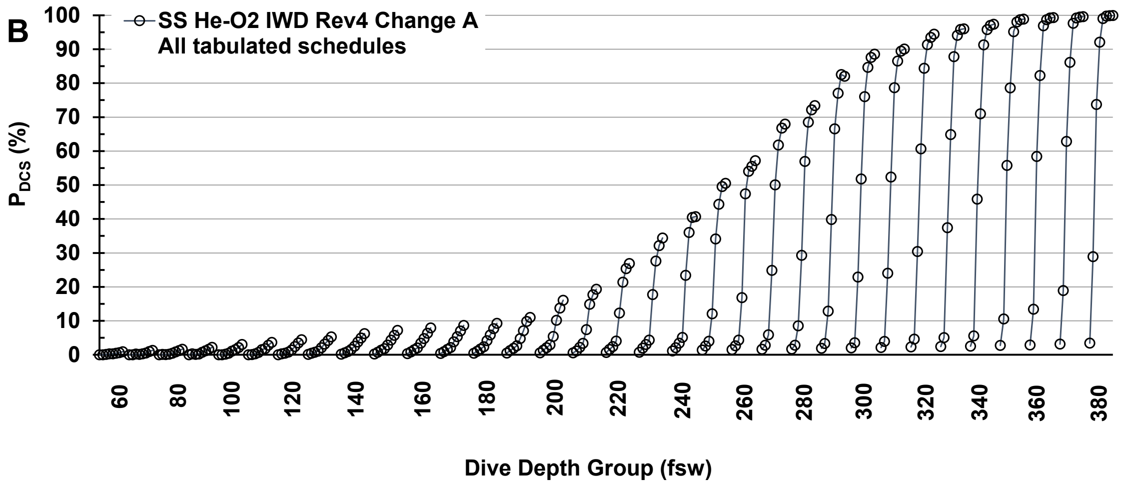

Figure 1-B. LEM-he8n25 model-estimated risks of DCS for all tabulated in-water decompression schedules in the current U.S. Navy Surface-Supplied Helium-Oxygen Decompression Table, including the higher risks for exceptional exposure dives. Risks were computed assuming that heliox with the maximum allowed oxygen fraction at each dive depth is breathed for an inspired PO_2 of 1.3 atm at each depth. Schedules, each represented by an open circle, are ordered by increasing bottom times in groups of increasing dive depth. Lines between points are shown for clarity only.

METHODS

Present work was based on probabilistic models which provide estimates of DCS incidence and time of occurrence as close as possible to observed outcomes in compilations of laboratory chamber dive data selected for model training. Such models allow determination of the shortest possible decompressions from dives that incur a user-specified estimated risk of DCS. At the outset of this work the LEM-he8n25 model developed for production of the U.S. Navy MK 16 MOD 1 1.3 atm PO_2-in-He decompression schedules[10] was the only available probabilistic model applicable to heliox diving. However, it was noted during development of this model that lack-of-fit to its he8n25 training data is concentrated on three particular subsets of that data: the heliox dive data set **DC8416W**, and the air saturation dive data sets **ASATNSM** and **ASATEDU**.[10] While the model underestimates the observed risks of DCS in the air saturation dives, it seriously over-estimates the observed risks in the **DC8416W** dives, dives in the he8n25 data compilation that are similar to U.S. Navy surface-supplied heliox dives. Bottom gas mix of 84% He/16% O_2 (84/16 heliox) was breathed in the **DC8416W** dives until being switched to air during decompression beginning at depths as deep as 160 fsw, depending on bottom depth, and to 100% O_2 at a 30 fsw last stop. The overestimation of DCS risks for the **DC8416W** dives motivated suspicion that the algorithm for computing decompression schedules with the LEM-he8n25 model would yield overly conservative schedules for SS He-O_2 decompressions.

Present work commenced with efforts to develop a potentially more suitable probabilistic model for generating SS He-O_2 decompression schedules. Schedules produced with different probabilistic models were then compared to schedules in the current U.S. Navy SS He-O_2 Decompression Table and the current U.S. Navy 1.3 atm constant PO_2-in-He decompression table for the MK 16 MOD 1 EC-UBA. These comparisons became the basis for selection of a final candidate replacement SS He-O_2 Decompression Table for man-testing.

Models and Model Optimization

Probabilistic models of two classes were evaluated: Linear-Exponential Multi-gas (LEM) gas content models and 3-Region Unstirred Tissue (3RUT) gas and bubble dynamics models. Each was based on the idealization of the tissues involved in DCS as three parallel-perfused tissue compartments with gas contents that change with gas exchange between lung, blood, and tissue. In the LEM model class described in detail in NEDU TR 02-10,[10] the risk of DCS is a function of prevailing compartmental gas contents throughout a dive profile. In the different forms of the 3RUT model class described in NEDU TR 18-01,[18] the risks of DCS are increasingly complex functions of the modeled profusion and size of gas bubbles in hypothetical parallel-perfused tissue compartments.

The simplest of the 3RUT model structures described in NEDU TR 18-01, the 3RUTSB model, was the first to be evaluated. In this model, only a single bubble is considered able to nucleate and evolve in any compartment, oxygen is considered as a fixed partial pressure, infinitely diffusible dissolved gas, and exercise effects on compartmental gas exchange kinetics and bubble nucleation are neglected. The model was implemented in its scaled form described in NEDU TR 18-01. Linked partial differential equations for blood-tissue and tissue-bubble gas exchange and bubble evolution and were solved numerically under the quasi-static assumption. Solution of the equations using the simplifying piece-wise analytic approximation described in NEDU TR 18-01 was attempted but abandoned on encounter of unreconcilable numerical instabilities. Long computation times required to solve the equations for each dive profile precluded consideration of more complex 3RUT models. LEM models proved to be more tractable as described below.

The models were parameterized by likelihood maximization[19] with custom-written FORTRAN software to provide estimates of DCS incidence and times of occurrence as close as possible to observed DCS incidences and times of occurrence in compilations of laboratory chamber dive data selected for model training.

Training Data

Model training data comprised the he8n25 training data for the legacy LEM-he8n25 model and an expansion of that data named HeN2_2016 [20] that included more man-trial results from heliox and fixed oxygen fraction (FO_2) dives relevant to SS He-O_2 diving. The **DC8416W** data included in both the he8n25 and HeN2_2016 data compilations is augmented in HeN2_2016 by addition of data from two additional subject populations that participated in these dives. **DC8416WET** contains the **DC8416W** data in he8n25 from “wet” divers and **DC8416d** and **DC8416s** contain additional data from dry resting “divers” and “supervisors,” respectively, that accompanied the wet, water-immersed and exercising divers in adjoining sections of the chamber complex.

The compositions of the he8n25 and HeN2_2016 data are given in Table 1. Data subsets in the HeN2_2016 compilation with the suffix “ET” included added information about diver thermal status and exercise performed in each recorded exposure as obtained from reviews of original library dive logs. These reviews resulted in modification of exposure and DCS incidence counts in three subsets of the he8n25 compilation, as highlighted in the table. Air saturation data subsets **ASATNEDU** and **ASNSM** included in the he8n25 compilation were omitted in HeN2_2016.

The LEM model structure was optimized about the HeN2_2016 data compiled with water vapor pressure (PH_2O) equal to zero in all inspired gases for consistency with the assumed inspired gas and tissue PH_2O in the legacy LEM-he8n25 model to produce the LEM-HeN2_2016 model. For fitting the 3RUTSB model, both he8n25 and HeN2_2016 were recompiled from original sources to accommodate inspired gas saturated with PH_2O of 47 mm-Hg in closed circuit UBA dives.

Table 1. Training Data for Probabilistic Models

	he8n25						HeN2_2016					
	Data Set	# Exposures	# DCS Incidents				Data Set	# Exposures	# DCS Incidents			
			Observed						Observed			
					DCS + marginals[a]						DCS + marginals[a]	
		(N)	DCS	marginals	(f)	p (= f / N)		(N)	DCS	marginals	(f)	p (= f / N)
helium-based dives	DC8416W	182	4	0	4	0.022	DC8416WET	182	4	0	4	0.022
	DRATMXW	190	10	10	11	0.058	DRATMXWET	192	10	10	11	0.057
	EDU185s	1582	57	2	57.2	0.036	EDU185sET	1582	57	2	57.2	0.036
	EDUHe70	264	31	3	31.3	0.119	EDUHe70ET	280	33	3	33.3	0.119
	NMR86h6	62	1	0	1	0.016	NMR86h6ET	62	1	0	1	0.016
	NMR9404	472	26	22	28.2	0.060	NMR9404ET	472	26	22	28.2	0.060
	NSMTMX	69	4	0	4	0.058	NSMTMX	69	4	0	4	0.058
							DC8416s	93	7	0	7	0.075
							DC8416d	440	14	2	14.2	0.032
							EDU0210mk16mod1	598	8	0	8	0.013
							EDU1204HeN2ET	103	0	1	0.1	0.001
							EDU1404trimixET	96	2	0	2	0.021
							EDUNsatHexcET	25	1	0	1	0.040
							EDUTRMXsubsat	38	13	1	13.1	0.345
nitrogen-oxygen	EDU1180S	120	10	0	10	0.083	EDU1180SET	120	10	0	10	0.083
	EDU885A	483	30	0	30	0.062	EDU885AET	483	30	0	30	0.062
	EDU885M	81	4	0	4	0.049	EDU885MET	81	4	0	4	0.049
	EDU885S	94	4	0	4	0.043	EDU885SET	94	4	0	4	0.043
	NMR8697	477	11	18	12.8	0.027	NMR8697ET	477	11	18	12.8	0.027
	NMR94EOD	284	16	13	17.3	0.061	NMR94EODE	284	17	9	17.9	0.063
	NSM6hr	57	3	2	3.2	0.056	NSM6hrE	57	3	2	3.2	0.056
	ASATNSM	132	18	21	20.1	0.152	---	---	---	---	---	---
	ASATEDU	120	13	27	15.7	0.131	---	---	---	---	---	---
							DC4wET	244	8	4	8.4	0.034
							DC4wrET	12	3	0	3	0.250
							DC8AOwET	46	3	1	3.1	0.067
							DC8ASURwET	98	5	0	5	0.051
							DCSUREPwET	17	1	0	1	0.059
							EDU0504dissubtend	126	3	0	3	0.024
							EDU184ET	239	11	0	11	0.046
							EDU1106deepstopsET	391	13	2	13.2	0.034
							EDU885ARET	182	11	0	11	0.060
							NMRNSW2ET	91	5	5	5.5	0.060
							PAMLAODET	134	6	0	6	0.045
							PAMLAOSET	140	5	3	5.3	0.038
							PARAET	135	7	3	7.3	0.054
	TOTALS	4669	242.0	118.0	253.8		TOTALS	7683	340.0	88.0	348.8	

[a] each DCS marginal counted as 0.1 DCS

Candidate Replacement Table Generation

Tables of SS He-O_2 decompression schedules were computed for consideration as candidate replacements for the current table in the *U.S. Navy Diving Manual*. The schedules were computed using an NEDU implementation of an iterative search algorithm described by Survanshi, et al.[21] with the 3RUTSB and LEM probabilistic models fit to the he8n25 and HeN2_2016 training data. The algorithm yields the shortest decompression schedule for a given dive depth and bottom time that incurs an estimated risk of DCS closest to but not exceeding a user-specified risk of DCS according to the probabilistic model used and other schedule optimization conditions and rules.

A range of usable bottom mix O_2 fractions was specified for each dive depth to keep prescribed diver-inspired PO_2 within acceptable limits. The O_2 fraction maxima were specified to keep diver inspired PO_2 equal to or less than 1.3 atm in accord with the O_2 fraction maxima in the current SS He-O_2 schedules. 16%, 12%, and 10% O_2 fraction minima were adopted from those used to aggregate the 1950 Molumphy partial pressure tables into the Minimum/Maximum Percent Oxygen format of the current SS He-O_2 table.[8] A 21% O_2 fraction minimum was introduced to allow more efficient decompressions in shallower dives. The maximum depth at which each minimum FO_2 mix could be used was then specified as the deepest depth at which the PO_2 of the mix did not exceed 1.3 atm. At this depth the minimum and maximum FO_2 are the same. At the next deeper depth, the minimum FO_2 was incremented to the next lower FO_2. Candidate replacement schedules were computed assuming the minimum allowed diver-inspired FO_2 at each dive depth.

Schedules were first computed with the bottom mix FO_2 minima given in Table 2 and illustrated in Figure 2. It was later recognized that these minima did not accommodate a ±0.5% gas mixing error allowed in the *U.S. Navy Diving Manual*.[1] With this allowance, gases mixed to the minimum FO_2 values in Table 2 could have the actual FO_2 values given in Table 3 and illustrated in Figure 3. Revised schedules were computed assuming the minimum bottom mix FO_2 values in Table 3 adjusted for this allowed error. Depth maxima for the mixes, also given in Table 3 and illustrated in Figure 3, were also adjusted to avoid exceeding a 1.3 atm inspired PO_2.

Table 2. Bottom Mix FO_2 Minima in Initial Candidate Replacement SS He-O_2 Decompression Table

Dive Depth (fsw)	Percent O_2 (Balance He)	PO_2 Range (atm)
60-170	21	0.592 – 1.292
180-230	16	1.033 – 1.275
240-320	12	0.993 – 1.284

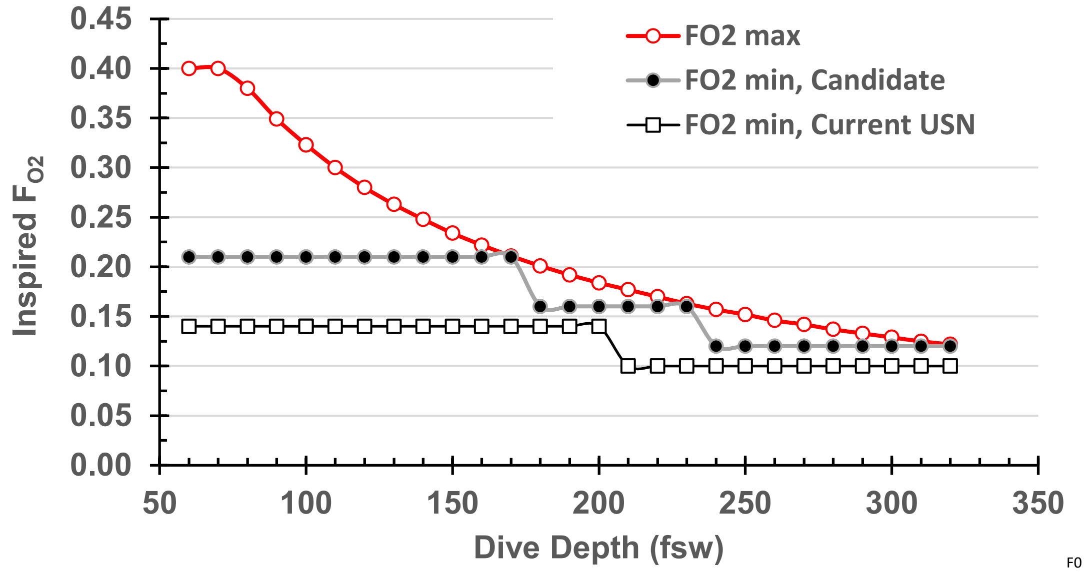

Figure 2. Inspired FO_2 limits for initial candidate SS He-O_2 replacement schedules. Lines between points are shown for clarity only.

Table 3. Bottom Mix FO_2 Minima in Revised Candidate Replacement SS He-O_2 Decompression Table

Dive Depth (fsw)	Target or "nominal" mix FO_2 (%)	Minimum actual mix FO_2 (%) [a]	Maximum actual mix FO_2 (%)	PO_2 Range (atm) [b]
60-160	21	20.5	21.5	0.578 – 1.257
170-220	16	15.5	16.5	0.973 – 1.265
230-310	12	11.5	12.5	0.917 – 1.299
320-380	10	9.5	10.5	1.016 – 1.314

[a] As assumed for table generation

[b] Includes accommodation for ±0.5% gas mixing error

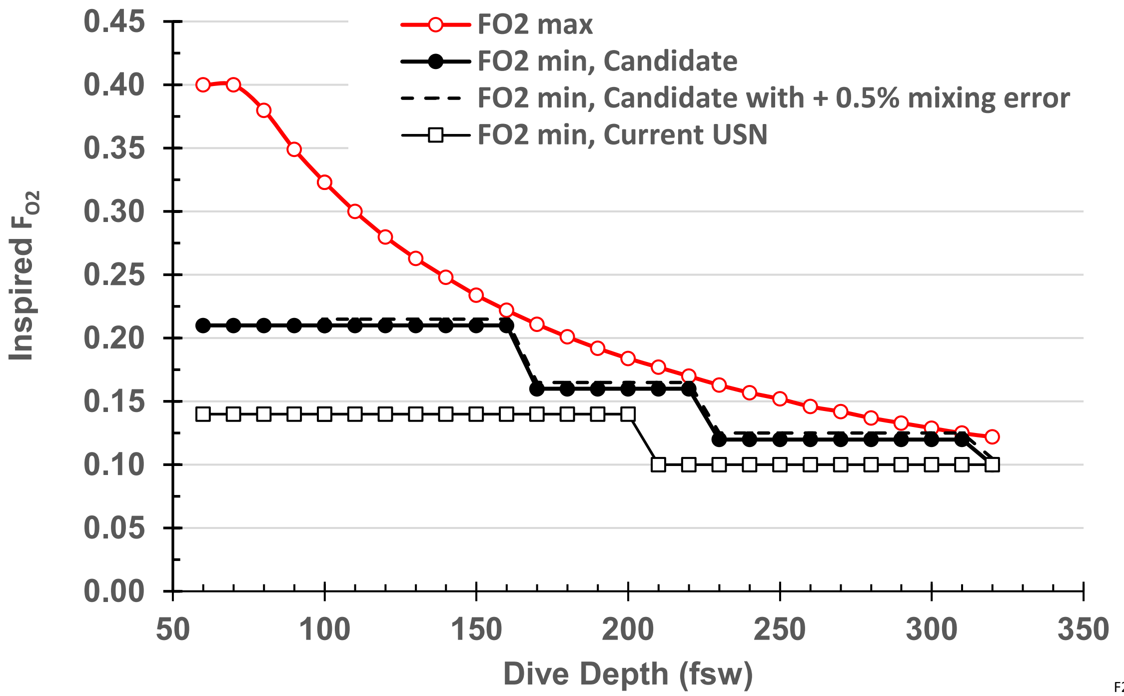

Figure 3. Inspired FO_2 limits for revised candidate SS He-O_2 replacement schedules. The 10 fsw reduction of the initial maximum allowed depth for each candidate bottom mix FO_2 prevents the PO_2 at the maximum allowed depths from exceeding 1.3 atm after accommodation for the +0.5% allowed gas mixing error. Lines between points are shown for clarity only.

The following additional conditions and rules were applied:

- Depth-dependent breathing gas shifts typical of surface-supplied heliox diving operations (Gas switch times were not included):
  - Breathing of bottom mix throughout the dive was assumed until a gas switch during decompression at 90 fsw or shallower, except:
    If bottom mix less than 16% O_2, air breathing assumed for initial descent to 20 fsw followed by switch to bottom mix during 10-minute hold before resumption of descent to bottom depth
  - Shift to 50/50 He-O_2 at 90 fsw stop, or if no 90 fsw stop, at first stop shallower than 90 fsw and deeper than 30 fsw
  - Shift to 100% (nominally, coded as 90%) oxygen at 30 fsw for in-water decompression
- 2.3% acceptable risk of DCS according to the LEM-HeN2_2016 model
- Assumed 75 fsw/min descent rate and 30 fsw/min ascent rate
- 10 fsw stop depth increment
- 200 fsw deepest allowed decompression stop
- 20 fsw shallowest allowed in-water decompression stop
- Stop times computed to 1 minute resolution

- In the initial candidate replacement schedules, each decompression stop time except the first in a schedule included travel time to the stop
- In the revised candidate replacement schedules, each decompression stop time except the first in a schedule and stops with a gas switch included travel time to the stop
- Eligible for $SurDO_2$ upon completion of 40 fsw in-water stop
- Number of chamber O_2 periods for $SurDO_2$ in each schedule was determined by rule from the 30 and 20 fsw in-water stop times as follows:
  The sum of the 30 and 20 fsw in-water stop times was rounded to the next highest multiple of 30 minutes and divided by 30 to obtain the number of 30-minute chamber O_2 periods
- A recommended 5-minute air-breathing break after each 30 minutes of oxygen breathing during in-water decompression or $SurDO_2$ was not included in the calculated schedules

RESULTS AND DISCUSSION

Model Evaluation

Models Fit to he8n25 Data

Numerical integration of the 3RUTSB model only became stable by employing a much shorter integration time interval than the LEM model. In comparison to LEM model fits that typically require integration time intervals between 1.5×10^{-2} and 3×10^{-1} minutes or less, the 3RUTSB model required an integration time interval no longer than 5×10^{-5} minutes for consistent model fits. The 3RUTSB model was fit with this shorter interval to the he8n25 data to yield the 3RUTSB-he8n25 model with parameter values given in Appendix A. Goodness-of-fit results are given in Table 4, including those for the legacy LEM-he8n25 model. With the 5×10^{-5}-minute integration time interval, the computation time required to solve the 3RUTSB model on any given profile was prohibitively long, thwarting attempts to fit it to the larger HeN2_2016 data set.[d] Computation time was considerably reduced by increasing the integration time interval from 5×10^{-5} minutes to 5×10^{-4} minutes, but not enough to overcome the prohibitively long times required to fit the model to the HeN2_2016 data. The impact of this integration interval increase on model performance with the same parameter values is shown in Table 4 and Figure 4. Discrepancies were limited to the **EDU185S** data subset, which is actually fit better by the model when solved with the increased integration interval. The reason for this is unclear, except that the **EDU185S** data are for constant diver inspired PO_2 dives in which the inspired FO_2 varies with depth. In the absence of a satisfactory explanation as the source of the numerical instability, caution must be exercised any time the larger integration time interval is used with the 3RUTSB model.

[d] Note: A profile is the history of diver depth, breathing gas, exercise, thermal status, and outcome common to each of one or more man-dives or exposures. Multiple exposures on a given profile are common, particularly if the exposures were completed DCS-free.

Table 4. Model Goodness-of-fit to Original he8n25 Data with PH_2O=0 and Recompiled he8n25 Data with PH_2O=47 mm-Hg

Data				Model								
		Observed		Predicted								
				LEM-he8n25			3RUTSB-he8n25 5xE-5			3RUTSB-he8n25 5xE-4		
Data SubSet	# Exposures						(fitted w/dTi=5x10^{-5} min)			(5xE-5 model solved w/dTi=5x10^{-4} min)		
		# DCS[a]		# DCS[a]		Pearson Residual^2	# DCS[a]		Pearson Residual^2	# DCS[a]		Pearson Residual^2
	(N)	(f)[a]	p (= f / N)	(n)	p (= n / N)	(f-n)^2/n(1-p)	(n)	p (= n / N)	(f-n)^2/n(1-p)	(n)	p (= n / N)	(f-n)^2/n(1-p)
$He\text{-}O_2$												
EDU185S	1582	57.2	0.036	73.4	0.046	3.751	86.0	0.054	10.196	66.1	0.042	1.256
EDUHE70	264	31.3	0.119	30.7	0.116	0.015	20.6	0.078	5.970	20.6	0.078	5.993
NMR86H6	62	1	0.016	3.9	0.063	2.315	1.4	0.022	0.099	1.4	0.022	0.099
NSMTMX	69	4	0.058	3.4	0.049	0.109	4.5	0.066	0.069	4.5	0.065	0.062
DC8416W	182	4	0.022	16.6	0.091	10.560	10.7	0.059	4.425	10.7	0.059	4.415
DRATMXW	190	11	0.058	8.5	0.045	0.782	4.2	0.022	11.516	4.2	0.022	11.516
NMR9404	472	28.2	0.060	22.2	0.047	1.708	18.6	0.039	5.182	18.6	0.039	5.185
$N_2\text{-}O_2$												
NMR94EOD	284	17.3	0.061	14.5	0.051	0.592	9.9	0.035	5.710	9.9	0.035	5.712
NSM6HR	57	3.2	0.056	3.8	0.067	0.103	3.5	0.062	0.035	3.5	0.062	0.035
EDU885A	483	30	0.062	21.9	0.045	3.153	28.9	0.060	0.047	28.9	0.060	0.048
EDU885M	81	4	0.049	3.0	0.038	0.312	5.3	0.065	0.342	5.3	0.065	0.342
EDU885S	94	4	0.043	4.1	0.043	0.002	4.9	0.053	0.190	4.9	0.053	0.190
EDU1180S	120	10	0.083	8.4	0.070	0.310	13.4	0.111	0.960	13.4	0.111	0.960
NMR8697	477	12.8	0.027	14.3	0.030	0.170	12.0	0.025	0.059	12.0	0.025	0.059
ASATNSM	132	20.1	0.152	10.6	0.080	9.219	22.1	0.167	0.209	22.1	0.167	0.209
ASATEDU	120	15.7	0.131	8.4	0.070	6.717	10.3	0.086	3.053	10.3	0.086	3.053
TOTALS	4669	253.8		247.8	χ^2=	39.817	256.3	χ^2=	48.063	236.3	χ^2=	39.136
					(df=15)	0.0005		(df=15)	P<0.0001		(df=15)	0.0006

[a] DCS incidents with each marginal counted as 0.1 DCS

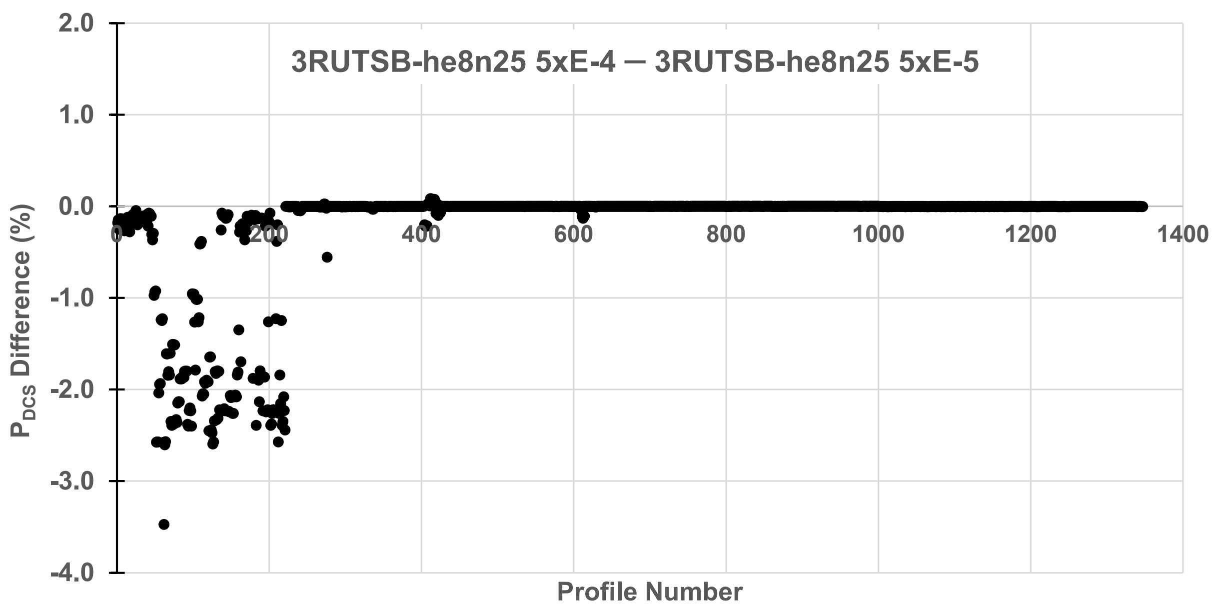

Figure 4. Comparison of 3RUTSB models performance on the 1347 profiles in the recompiled he8n25 data. The 3RUTSB-he8n25 5xE-5 and 3RUTSB-he8n25 5xE-4 models have identical parameter values but are exercised with integration time intervals of 5x10^{-5} and 5x10^{-4} minutes, respectively. As indicated in the goodness-of-fit results in Table 4, discrepancies are limited to the **EDU185S** data subset, which contains the first 221 profiles in the he8n25 compilation. Negative differences correspond to lower P_{DCS} values estimated by 3RUTSB-he8n25 5xE-4 than by 3RUTSB-he8n25 5xE-5.

The squared Pearson residuals for the 3RUTSB-he8n25 models on the **DC8416W** dives are substantially lower than those for LEM-he8n25, indicating an improved fit to these fixed FO_2 He-O_2 dives. However, the squared Pearson residuals for 3RUTSB-he8n25 models on the constant FO_2 He-O_2 dives in the **EDUHE70** and **NMR9404** data sets are substantially higher than those for LEM-he8n25, indicating worsened fits to these dives.

None of the models passed the global chi-square criterion of $P>0.05$ for acceptable fit to the he8n25 data. Nevertheless, the LEM-he8n25 model was shown in earlier work to provide a satisfactory fit to all he8n25 data except that in the **DC8416W**, **ASATNSM**, and **ASATEDU** data subsets, data not relevant to constant PO_2-in-He diving. On the basis of its satisfactory fit to other constant PO_2-in-He dive data in he8n25, LEM-he8n25 was successfully used to develop the table for constant 1.3 atm PO_2-in-He diving with the MK 16 MOD 1 in the current *U.S. Navy Diving Manual*.[1] Similarly, the 3RUTSB model was retained as a contender for development of a replacement SS He-O_2 decompression table because of its fit to the **DC8416W** data in he8n25 despite its worsened fit to constant PO_2-in-He data.

Figure 5 illustrates the estimated risks of DCS of in-water decompression schedules for dive depths of 200 to 300 fsw in the current USN SS He-O_2 decompression table as estimated with the 3RUTSB-he8n25 models. As for the estimates of DCS risk in Figure 1, the risk estimates in Figure 5 were computed assuming that heliox with the maximum allowed oxygen fraction at each dive depth is breathed for an inspired PO_2 of 1.3 atm at depth. Performance of the two 3RUTSB-he8n25 models on these schedules is indistinguishable, indicating that features that distinguish the performance of these models are not present in SS He-O_2 diving and that the 3RUTSB-he8n25 model fit with a $5x10^{-5}$-minute integration interval but solved with a $5x10^{-4}$-minute integration interval can be used for application to these dives. Unless otherwise noted, the 3RUTSB-he8n25 model fit with a $5x10^{-5}$-minute integration interval was solved with a $5x10^{-4}$-minute integration interval in all ensuing 3RUTSB-he8n25 model applications.

Notably, the 3RUTSB model estimates of DCS risk are markedly lower than the LEM-he8n25 model estimates for longer dives in each dive depth group. Although lower than the LEM-he8n25 estimates, the 3RUTSB estimates still indicate that the longer dives have unacceptable risks of DCS. This result is consistent with the suspicion that LEM-he8n25 overestimates risks of DCS for longer deeper dives in the current USN table, though the magnitudes of the indicated overestimations by LEM-he8n25 are surprisingly large. Figure 6 illustrates 3RUTSB-he8n25 model-estimated risks of DCS of all tabulated in-water SS He-O_2 decompression schedules in the *U.S. Navy Diving Manual*.

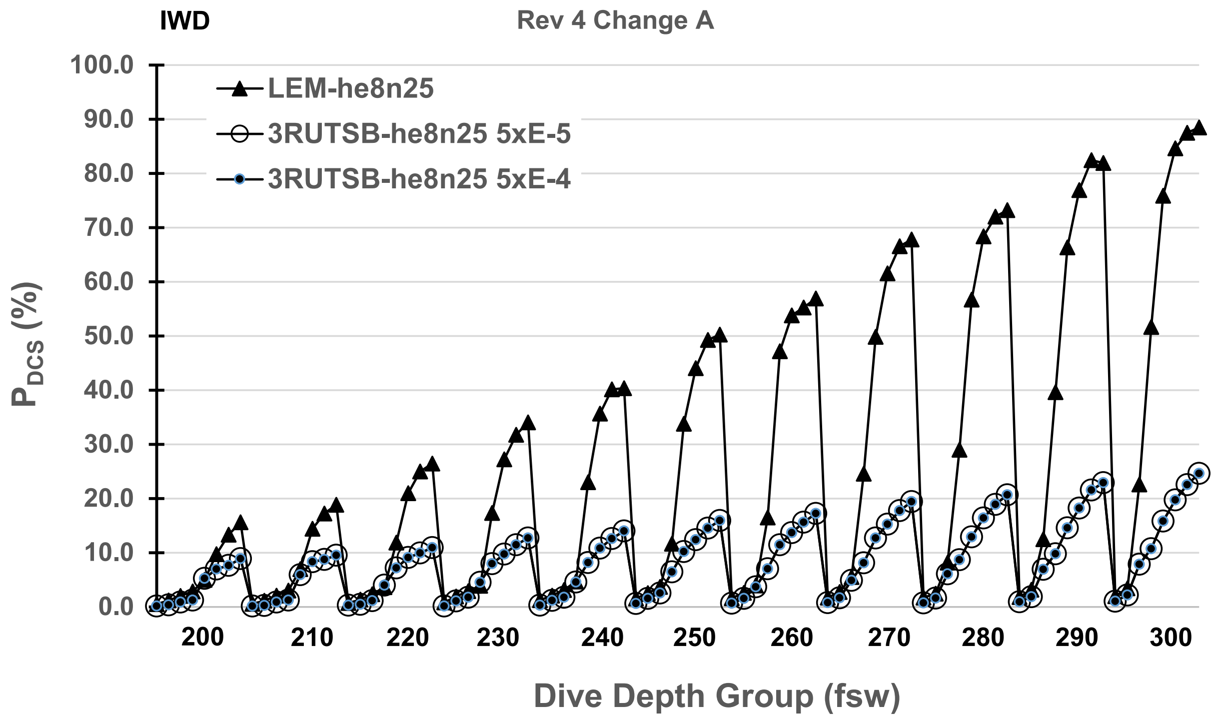

Figure 5. Model-estimated risks of DCS of normal and exceptional exposure schedules for selected depths in the surface-supplied heliox decompression table in the *U.S. Navy Diving Manual*. Risks were computed assuming the maximum allowed oxygen fraction at each dive depth, for an inspired PO_2 of 1.3 atm at depth. Schedules are ordered by increasing bottom times in groups of increasing dive depth. Both normal exposure and exceptional exposure schedules are included for each dive depth group. Lines between points are shown for clarity only.

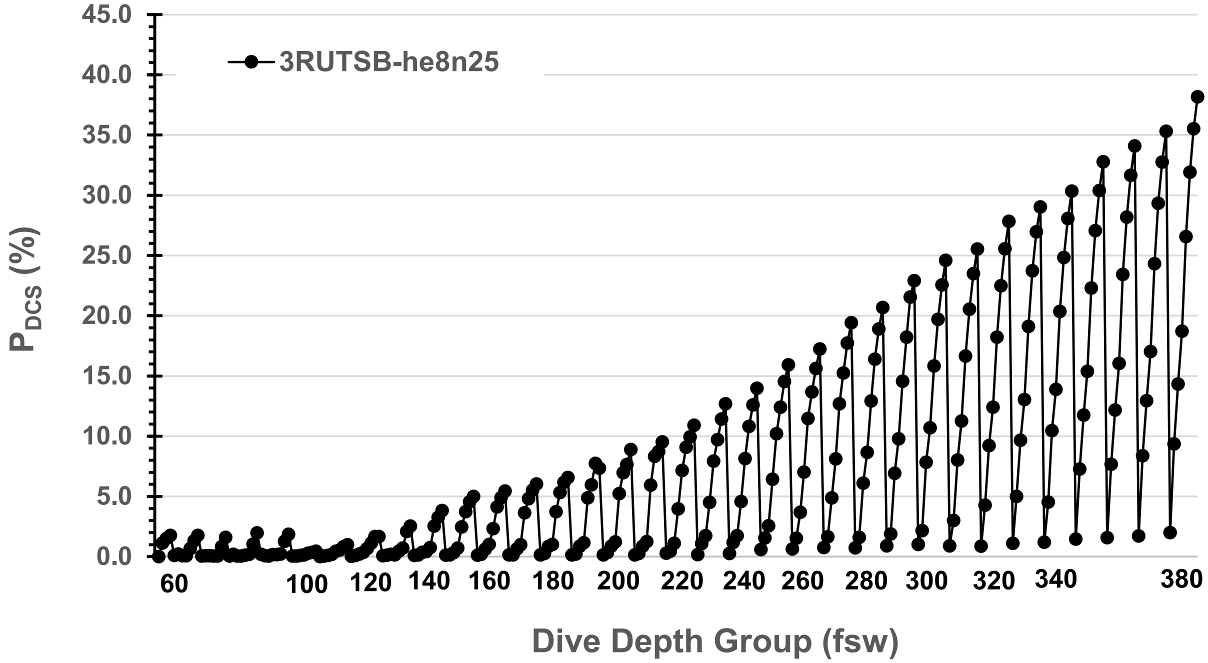

Figure 6. 3RUTSB-he8n25 model-estimated risks of DCS of all tabulated in-water SS He-O_2 decompression schedules in the *U.S. Navy Diving Manual*. Schedules are ordered by increasing bottom times in groups of increasing dive depth. Risks were computed assuming the maximum allowed oxygen fraction at each dive depth, for an inspired PO_2 of 1.3 atm at depth. Both normal exposure and exceptional exposure schedules are included for each dive depth group. Lines between points are shown for clarity only.

LEM and 3RUTSB-he8n25 Model Performance on HeN2_2016 Data

The long computation times required to solve the 3RUTSB model on SS He-O_2 profiles thwarted attempts to fit the model to the larger HeN2_2016 data set and take advantage of model performance improvements potentially afforded by the increased representation of fixed oxygen fraction dives in this data set. However, the more computationally tractable LEM model was successfully optimized about this data, yielding the LEM-HeN2_2016 model with parameters given in Appendix B. The model formally failed on two DCS cases in the data; one in **EDU0504dissubtend** and one in **PAMLAOSET**; with failure to manifest DCS risk in the T1 – T2 intervals for these exposures. Each T1 – T2 interval is the period between the time the subject was last reported DCS-free (T1) and the time the subject was first diagnosed with DCS (T2). The two failures have unusually high T1 and T2 times; T1 = 2952.0 and T2 = 5669.0 minutes for the failure in **EDU0504dissubtend**, and T1 = 530.2 and T2 = 710.2 minutes for the failure in **PAMLAOSET**. The LEM model is ill-suited to produce risk after such high T1 times because the model is only able to produce decreasing DCS risk after surfacing from a dive. Incidence-only estimates of risk for these exposures, which consider risk accumulation regardless of when the risk occurs, were 1.922% and 6.362% for the **EDU0504dissubtend** and **PAMLAOSET** failures, respectively. These survival fit failures were consequently not considered serious faults of the model.

Goodness-of-fit results for the 3RUTSB-he8n25 and LEM-HeN2_2016 models on the HeN2_2016 data are summarized in Table 5. Although none of the models passed the global chi-square criterion of P>0.05 for acceptable fit to the HeN2_2016 data, the LEM-HeN2_2016 model fit to this data has the lowest – and-best – chi square of all the models shown, both for the entire data set and the helium-based subset of these dives considered separately. The 3RUTSB models fit to the he8n25 data have the highest – and worst – chi-squares for both the entire HeN2_2016 data set and the helium-based dives.

The performance of both 3RUTSB models and the LEM-HeN2_2016 model was markedly improved over the performance of the LEM-he8n25 model on the **DC8416WET** and **DC8416d** data sets. Although the LEM-HeN2_2016 model still overestimates the incidents of DCS in the **DC8416WET** data, the LEM-HeN2_2016 squared Pearson residual for this data is a more favorable 5.424 compared to the 10.512 residual for LEM-he8n25. The LEM-HeN2_2016 model fit to the **DC8416d** data is also superior to the LEM-he8n25 fit, and comparable to the fits of the 3RUTSB models.

Table 5. Model Goodness-of-fit to HeN2_2016 Data

Data						Model											
		# DCS Incidents				[fit to he8n25]									[fit to HeN2_2016]		
		Observed				LEM-he8n25 Predicted			3RUTSB-he8n25 5xE-5 Predicted			3RUTSB-he8n25 5xE-4 Predicted			LEM-HeN2_2016 Predicted		
Data SubSet	# Exposures					(PH_2O=0 mm-Hg)			(dTi=5.0E-5 min) (PH2O=47 mm-Hg)			3RUTSB-he8n25 5xE-5 w/dTi=5.0E-4 min (PH2O=47 mm-Hg)			(PH_2O=0 mm-Hg)		
				DCS + marginals[a]		DCS + marginals		Pearson Residual[2]	DCS + marginals		Pearson Residual[2]	DCS + marginals		Pearson Residual[2]	DCS + marginals		Pearson Residual[2]
	(N)	DCS	marginals	(f)	p (= f / N)	(n)	p (= n / N)	(f-n)^2/n(1-p)	(n)	p (= n / N)	(f-n)^2/n(1-p)	(n)	p (= n / N)	(f-n)^2/n(1-p)	(n)	p (= n / N)	(f-n)^2/n(1-p)
He-based dives																	
DC8416WET	182	4	0	4	0.022	16.6	0.091	10.512	10.6	0.058	4.377	10.6	0.058	4.368	11.7	0.064	5.424
DC8416s	93	7	0	7	0.075	8.6	0.092	0.326	5.5	0.059	0.443	5.5	0.059	0.445	6.1	0.065	0.154
DC8416d	440	14	2	14.2	0.032	42.0	0.095	20.320	26.7	0.061	6.191	26.6	0.061	6.175	29.4	0.067	8.393
DRATMXWET	192	10	10	11	0.057	8.2	0.043	0.982	4.1	0.022	11.661	4.1	0.022	11.661	7.9	0.041	1.279
EDU185sET	1582	57	2	57.2	0.036	73.4	0.046	3.764	85.9	0.054	10.128	66.1	0.042	1.256	68.3	0.043	1.883
EDU0210mk16mod1	598	8	0	8	0.013	12.4	0.021	1.577	17.7	0.030	5.483	14.0	0.023	2.655	11.7	0.020	1.200
EDUHe70ET	280	33	3	33.3	0.119	33.0	0.118	0.003	21.5	0.077	7.052	21.5	0.077	7.076	25.2	0.090	2.825
EDU1204HeN2ET	103	0	1	0.1	0.001	3.0	0.029	2.894	5.8	0.056	5.955	5.8	0.056	5.954	1.8	0.017	1.608
EDU1404trimixET	96	2	0	2	0.021	3.5	0.036	0.640	3.3	0.034	0.515	3.1	0.032	0.390	3.1	0.032	0.400
EDUNsatHexcET	25	1	0	1	0.040	0.6	0.026	0.208	1.1	0.043	0.007	1.1	0.043	0.007	0.2	0.009	2.656
EDUTRMXsubsat	38	13	1	13.1	0.345	5.1	0.135	14.386	2.5	0.065	48.516	2.5	0.065	48.708	4.7	0.122	17.467
NMR86h6ET	62	1	0	1	0.016	3.9	0.063	2.315	1.4	0.022	0.099	1.4	0.022	0.099	3.9	0.063	2.324
NMR9404ET	472	26	22	28.2	0.060	22.2	0.047	1.711	18.4	0.039	5.387	18.4	0.039	5.391	19.8	0.042	3.734
NSMTMX	69	4	0	4	0.058	3.4	0.049	0.107	4.5	0.066	0.070	4.5	0.065	0.063	1.6	0.023	3.622
N_2-O_2 based dives																	
DC4wET	244	8	4	8.4	0.034	5.0	0.021	2.314	4.4	0.018	3.762	4.4	0.018	3.762	5.9	0.024	1.040
DC4wrET	12	3	0	3	0.250	0.7	0.056	8.621	0.8	0.063	7.185	0.8	0.063	7.185	0.7	0.060	7.714
DC8AOwET	46	3	1	3.1	0.067	1.0	0.021	4.723	1.2	0.027	2.932	1.2	0.027	2.932	1.1	0.024	3.811
DC8ASURwET	98	5	0	5	0.051	3.3	0.034	0.877	1.6	0.016	7.434	1.6	0.016	7.434	3.1	0.032	1.219
DCSUREPwET	17	1	0	1	0.059	0.5	0.030	0.474	0.2	0.011	3.658	0.2	0.011	3.658	0.6	0.036	0.262
EDU0504dissubtend	126	3	0	3	0.024	3.1	0.025	0.005	2.3	0.018	0.218	2.3	0.018	0.218	2.2	0.018	0.285
EDU184ET	239	11	0	11	0.046	12.4	0.052	0.160	10.4	0.043	0.040	10.4	0.043	0.040	13.2	0.055	0.378
EDU1106deepstopsET	391	13	2	13.2	0.034	19.3	0.049	2.032	20.8	0.053	2.932	20.8	0.053	2.930	19.3	0.049	2.017
EDU1180SET	120	10	0	10	0.083	6.3	0.053	2.251	10.3	0.086	0.012	10.3	0.086	0.012	6.2	0.052	2.473
EDU885AET	483	30	0	30	0.062	21.9	0.045	3.153	28.9	0.060	0.047	28.9	0.060	0.047	22.5	0.047	2.641
EDU885ARET	182	11	0	11	0.060	8.8	0.048	0.570	8.0	0.044	1.188	8.0	0.044	1.188	10.0	0.055	0.117
EDU885MET	81	4	0	4	0.049	3.1	0.038	0.307	5.3	0.065	0.342	5.3	0.065	0.342	3.2	0.040	0.181
EDU885SET	94	4	0	4	0.043	4.1	0.043	0.002	4.9	0.053	0.190	4.9	0.053	0.189	4.1	0.043	0.001
NMR8697ET	477	11	18	12.8	0.027	14.3	0.030	0.171	12.0	0.025	0.058	12.0	0.025	0.059	15.4	0.032	0.448
NMR94EODE	284	17	9	17.9	0.063	14.4	0.051	0.884	9.9	0.035	6.675	9.9	0.035	6.677	13.9	0.049	1.180
NMRNSW2ET	91	5	5	5.5	0.060	4.7	0.052	0.145	4.7	0.051	0.156	4.7	0.051	0.156	4.6	0.051	0.187
NSM6hrE	57	3	2	3.2	0.056	3.8	0.067	0.103	3.5	0.062	0.035	3.5	0.062	0.035	3.5	0.061	0.027
PAMLAODET	134	6	0	6	0.045	7.7	0.057	0.388	8.4	0.062	0.715	8.4	0.062	0.715	6.7	0.050	0.086
PAMLAOSET	140	5	3	5.3	0.038	5.9	0.042	0.060	5.5	0.039	0.005	5.5	0.039	0.005	5.6	0.040	0.012
PARAET	135	7	3	7.3	0.054	7.8	0.058	0.038	6.9	0.051	0.027	6.9	0.051	0.028	8.4	0.062	0.150
TOTALS	7683	340.0	88.0	348.8	0.045	384.0	χ^2= (df=32)	87.021 P<0.0001	358.8	χ^2= (df=32)	143.493 P<0.0001	335.0	χ^2= (df=32)	131.860 P<0.0001	345.5	χ^2= (df=32)	77.200 P<0.0001
He-based subsets only:	4232	180	41	184.1	0.044	235.916	χ^2= (df=12)	59.745 P<0.0001	208.946	χ^2= (df=12)	105.883 P<0.0001	185.224	χ^2= (df=12)	94.248 P<0.0001	195.352	χ^2= (df=12)	52.971 P<0.0001

[a] marginal DCS counted as 0.1 DCS

Figure 7 illustrates the risks of DCS of in-water decompression schedules in the current USN SS $He-O_2$ decompression table as estimated with the LEM-HeN2_2016 model. As for the estimates of DCS risk in Figure 1, the risk estimates in Figure 7 were computed assuming that heliox with the maximum allowed oxygen fraction at each dive depth is breathed for an inspired PO_2 of 1.3 atm at each dive depth. The LEM-HeN2_2016 model estimates of DCS risk are slightly lower than the LEM-he8n25 model estimates for longer dives in each dive depth group, but still indicate that these dives have unacceptable risks of DCS. The LEM-HeN2_2016 model estimates are substantially higher than the 3RUTSB model estimates for these dives shown in Figures 5 and 6.

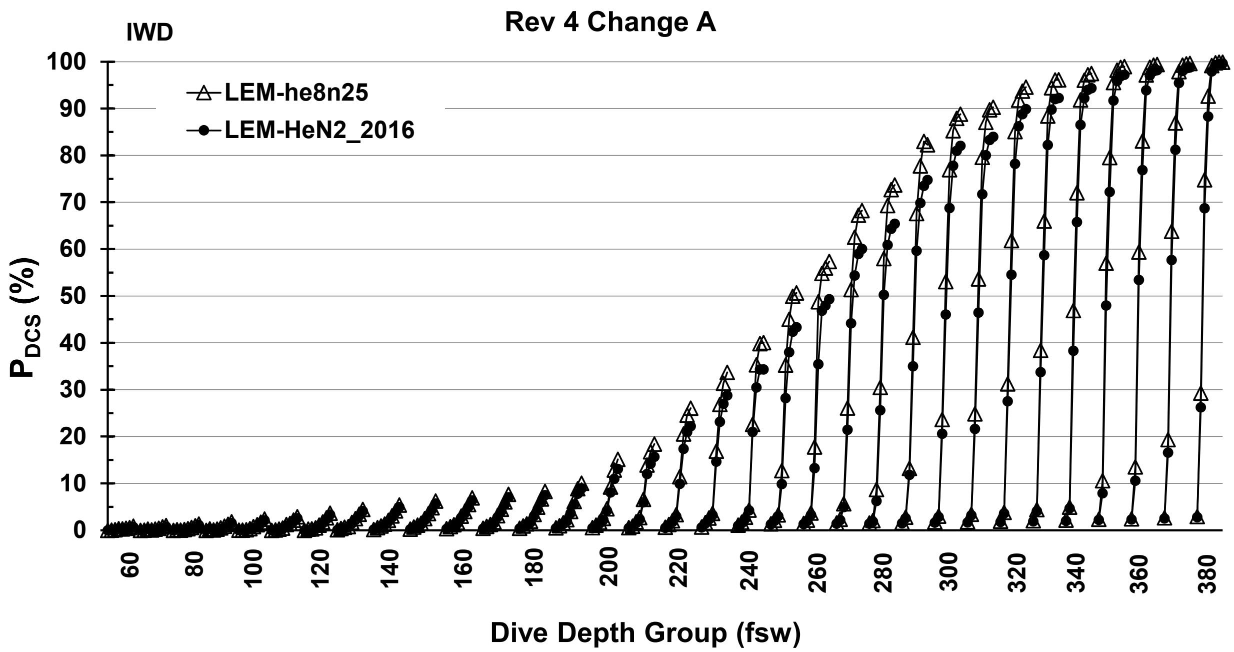

Figure 7. Risks of DCS of surface-supplied heliox decompression schedules in the *U.S. Navy Diving Manual* as estimated with the LEM-he8n25 and LEM-HeN2_2016 models. Schedules are ordered by increasing bottom times in groups of increasing dive depth. Risks were computed assuming the maximum allowed oxygen fraction at each dive depth, for an inspired PO_2 of 1.3 atm at depth. Both normal exposure and exceptional exposure schedules are included for each dive depth group. Lines between points are shown for clarity only.

Candidate Replacement SS $He-O_2$ Decompression Tables

Two candidate tables of replacement SS $He-O_2$ schedules were computed assuming minimum bottom gas oxygen fractions in Table 2. The first of these tables in Appendix C was computed with the 3RUTSB-he8n25 model. The other table in Appendix D was computed with the LEM-HeN2_2016 model. All schedules were computed to incur a 2.3% acceptable risk of DCS under the conditions and rules described in Methods. A table suitable for man-testing as a replacement for the current U.S. Navy SS He-O_2 schedules was selected from these initial tables.

Total decompression stop times of schedules computed with the 3RUTSB-he8n25 model are compared in Figure 8 to total stop times of schedules in the current U.S. Navy SS He-O_2 Decompression table. The relatively small change of the total stop times in the current table as dive depth increases is striking and consistent with the high estimated DCS risks of the schedules illustrated in Figure 1 for the longer deeper dives in this table. Schedules computed with the 3RUTSB-he8n25 model are uniformly shorter than corresponding schedules in the current USN SS He-O_2 Decompression table in dive depth groups shallower than 240 fsw. Total stop times in schedules for longer deeper dives become resolutely longer than those in the current USN table.

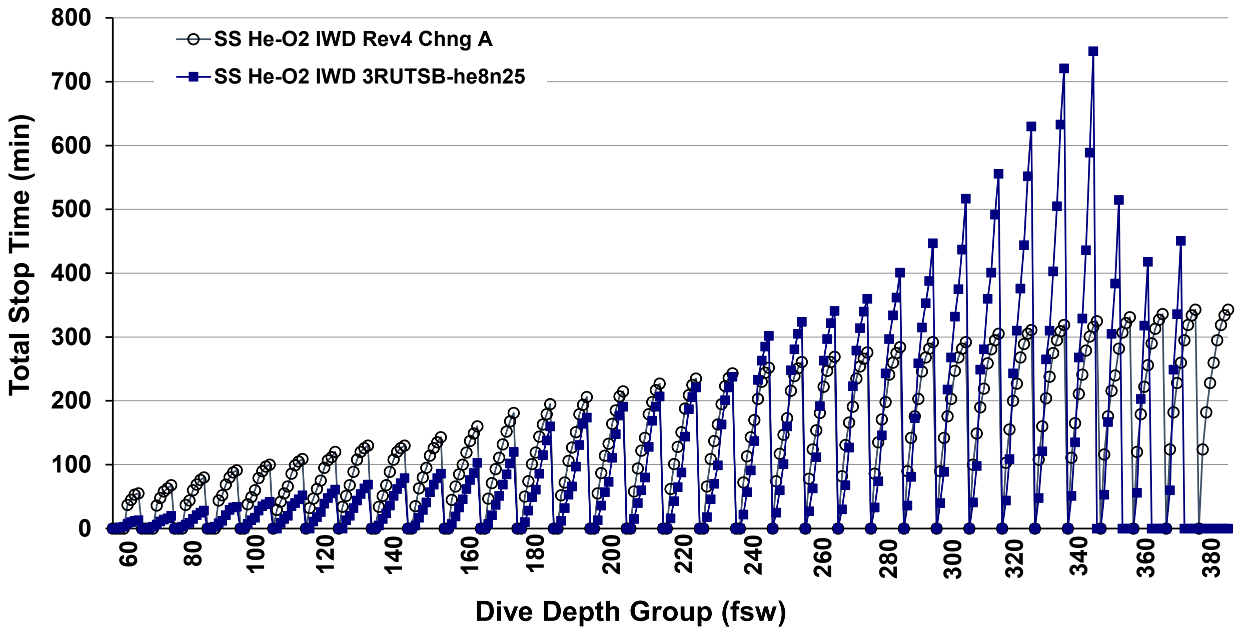

Figure 8. Total stop times of in-water SS He-O_2 decompression schedules computed with the 3RUTSB-he8n25 probabilistic model at 2.3% acceptable risk and bottom gas mixes in Table 2 compared to total stop times of in-water schedules in the current U.S. Navy SS He-O_2 Decompression table. Schedules are ordered by increasing bottom times in groups of increasing dive depth. Lines between points are shown for clarity only.

Total decompression stop times of schedules computed with the LEM-HeN2_2016 model are added in Figure 9 to the data in Figure 8. Schedules in the LEM-HeN2_2016 schedules for shorter bottom time dives in dive depth groups shallower than 240 fsw are comparable to those in the current USN table. As dive bottom times and depths increase, however, LEM-HeN2_2016 schedules tend to be substantially longer than those throughout the current USN table or those in the 3RUTSB-he8n25 table.

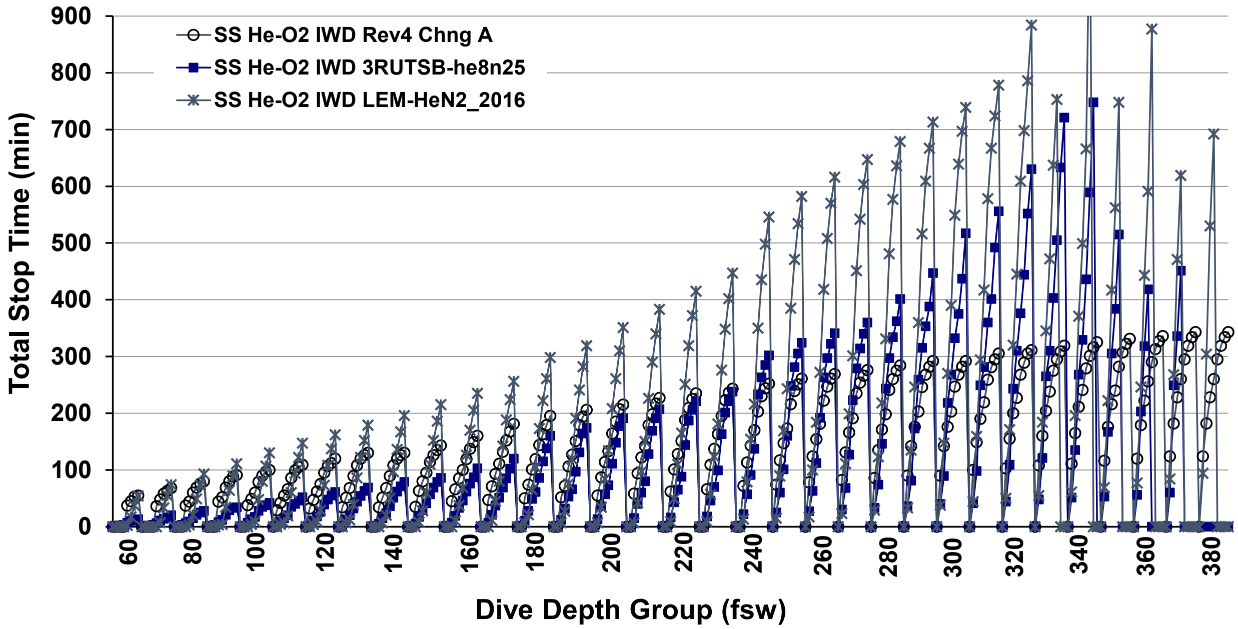

Figure 9. Total decompression stop times in in-water SS He-O_2 decompression schedules computed with 3RUTSB-he8n25 and LEM-HeN2_2016 probabilistic models at 2.3% acceptable risk and bottom gas mixes in Table 2 compared to the total decompression stop times of corresponding schedules in the current USN SS He-O_2 decompression table. Schedules are ordered by increasing bottom times in groups of increasing dive depth. The current USN table includes schedules for longer bottom times in deeper dive depth groups than are included in the candidate tables. Lines between points are shown for clarity only.

The shorter decompressions prescribed by the 3RUTSB-he8n25 model compared to those prescribed by the LEM-HeN2_2016 model are consistent with the lower risks of DCS estimated by the 3RUTSB-he8n25 model for schedules in the current USN table (Figures 5 and 6). Reducing the lower 3RUTSB-he8n25 model-estimated risks of DCS for the current schedules to the acceptable risk of 2.3% requires less additional decompression time than required to reduce the higher LEM-HeN2_2016 model-estimated risks to the same acceptable level.

Decompressions prescribed by the 3RUTSB-he8n25 model show the skew of total stop times to deeper stops typical of schedules prescribed by models that seek to limit the volumes of *in vivo* gas bubbles formed during and after decompression.[22] This skew is evident in comparisons of 90 fsw stop times in the 3RUTSB schedules to those in the current SS He-O_2 table shown in Figure 10. This skew is not manifest as strongly in the LEM-HeN2_2016 schedules. Figure 11 illustrates that 90 fsw stop times in the latter are comparable to those in the current table for dives to 250 fsw and shallower and for shorter dives to deeper depths. 90 fsw stop times are higher than those in the current table for longer dives to depths greater than 250 fsw, but remain substantially shorter than those in the 3RUTSB-he8n25 table.

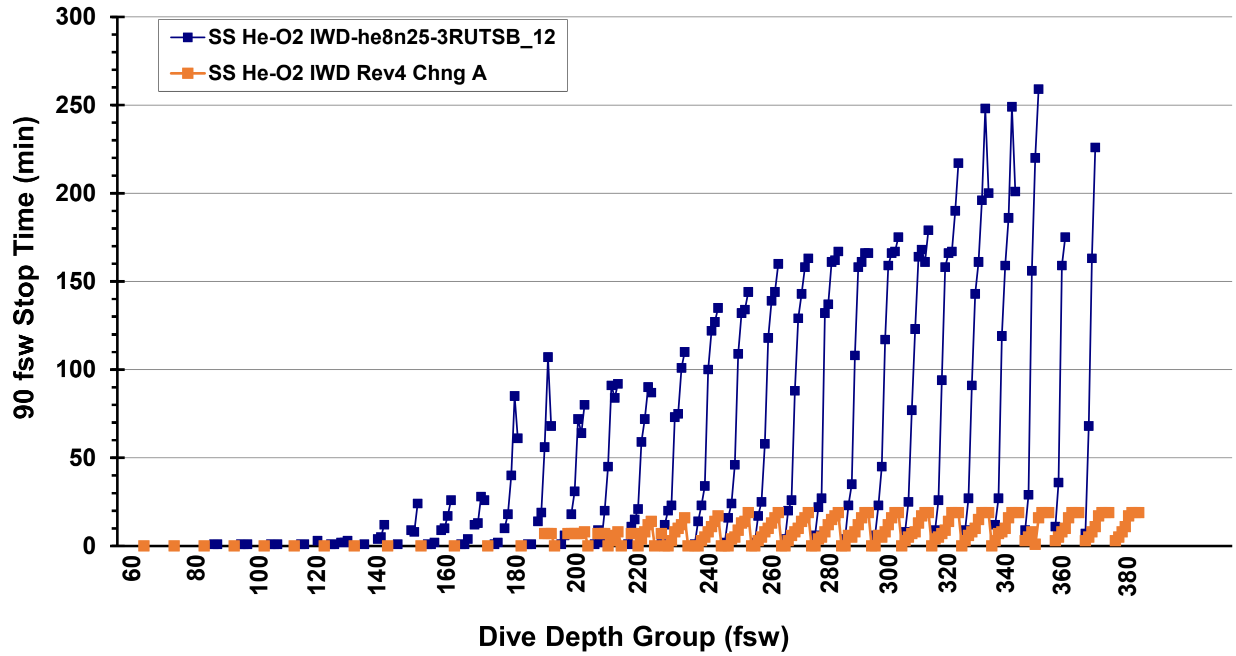

Figure 10. 90 fsw stop times in the 3RUTSB-he8n25 schedules and the current USN SS He-O_2 schedules. Schedules are ordered by increasing bottom times in groups of increasing dive depth. Lines between points are shown for clarity only.

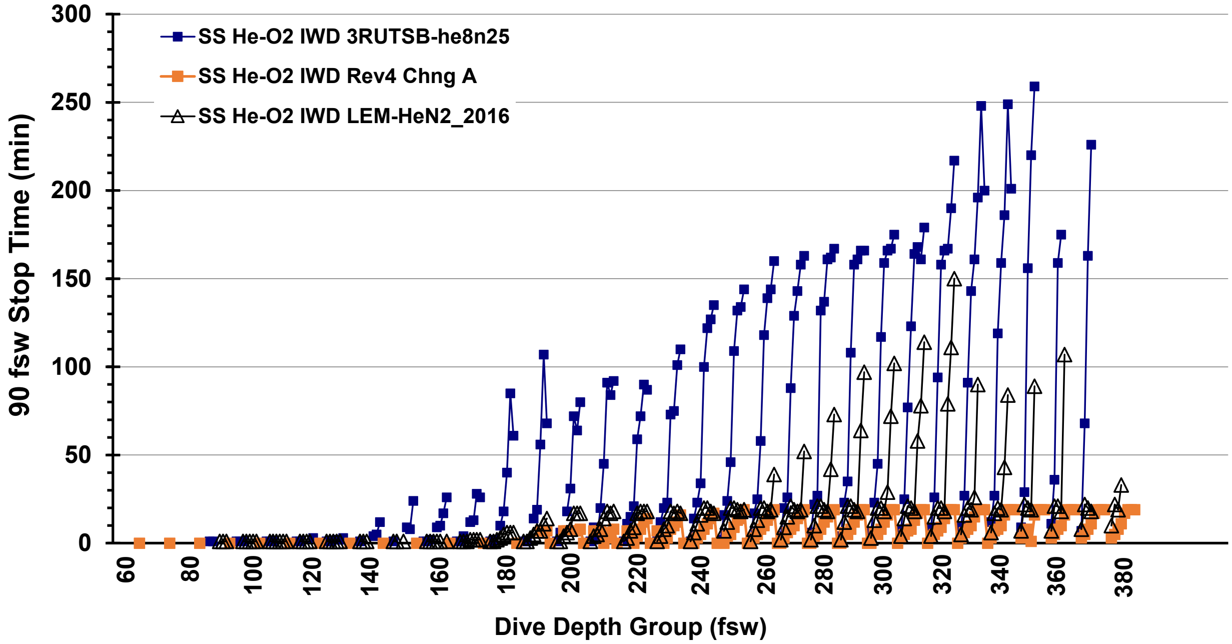

Figure 11. Comparison of 90 fsw stop times in the 3RUTSB, LEM-HeN2_2016, and current USN SS He-O_2 schedules. Schedules are ordered by increasing bottom times in groups of increasing dive depth. Lines between points are shown for clarity only.

The skew of stop times to deeper depths in the 3RUTSB-he8n25 schedules results in relatively short 30 and 20 fsw stops in the in-water schedules and fewer chamber O_2 periods for SurD than in the LEM-HeN2_2016 schedules. Although shorter than the LEM-HeN2_2016 schedules, the 3RUTSB-he8n25 schedules require more in-water decompression time before SurD becomes an option than required in the LEM-HeN2_2016 schedules (Figure 12). The times by which LEM-HeN2_2016 decompressions exceed 3RUTSB-he8n2 decompressions can consequently be completed in the safe refuge of a surface decompression chamber when SurD can be exercised.

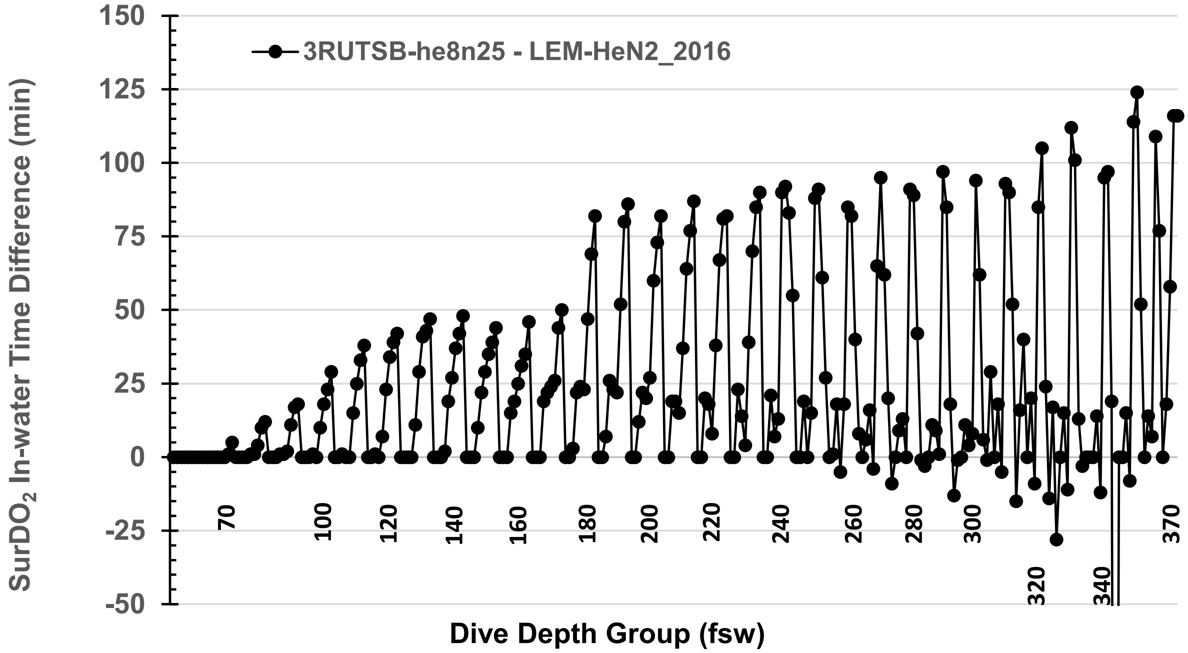

Figure 12. Difference in SurDO$_2$ in-water time between 3RUTSB-he8n25 and LEM-HeN2_2016 SS He-O$_2$ decompression schedules, ordered by increasing bottom times in groups of increasing dive depth (fsw). A single entry at -364 minutes for the 340 fsw/80 min schedules is out of range on the ordinate. Lines between points are shown for clarity only.

Comparisons to MK 16 MOD 1 Decompression Schedules

Specification of the MK 16 MOD 1 PO$_2$ of 1.3 atm as the maximum bottom PO$_2$ in the candidate SS He-O$_2$ schedules motivates comparison of these schedules to those in the current USN MK16 MOD 1 constant 1.3 atm PO$_2$-in-He decompression table, noting that all three sets of schedules were computed with a 2.3% acceptable risk of DCS, although with different models. All candidate SS He-O$_2$ schedules were computed assuming the minimum allowed bottom PO$_2$ at each dive depth, which is less than the MK 16 MOD 1 PO$_2$ unless at the maximum depth for a given bottom mix: 170, 230, or 320 fsw (Table 2). On the other hand, the PO$_2$ in the candidate SS He-O$_2$ schedules exceeds the MK 16 MOD 1 PO$_2$ of 1.3 atm at decompression stop depths of 90 to 60 fsw and 30 to 20 fsw (Table 6).

Table 6. Decompression Gas Mixes and Corresponding Inspired PO_2 in SS $He\text{-}O_2$ Decompression Tables at Stop Depths ≤ 90 fsw

Stop Depth (fsw)	Percent O_2	PO_2 (atm)
90	50	1.864
80		1.712
70		1.561
60		1.409
50		1.258
40[a]		1.106
In-water deco stops:		
30	90[b]	1.718
20[c]		1.445

[a] Last in-water stop for $SurDO_2$
[b] As assumed for table generation
[c] Last in-water stop for in-water decompression

Total stop time differences between in-water schedules in the candidate SS $He\text{-}O_2$ tables and corresponding schedules in the current MK 16 MOD 1 constant 1.3 atm PO_2-in-He table are shown in Figure 13. The LEM-HeN2_2016 schedules tend to be longer than their MK 16 MOD1 counterparts for dives to depths shallower than 130 fsw, consistent with the lower bottom PO_2 in the SS He-O2 schedules. Schedules in both candidate tables tend to be shorter than their MK 16 MOD 1 counterparts for long bottom time dives with substantial decompression stop times at 20, 30, and 60-to-90 fsw stops, as expected because inspired PO_2 at these stops is higher in SS $He\text{-}O_2$ decompressions than in MK 16 MOD 1 decompressions. This tendency begins at shallower depths in the 3RUTSB-he8n25 schedules and is much more marked at deeper depths than in the LEM-HeN2-2016 schedules. Both candidate replacement SS $He\text{-}O_2$ schedules thus compare consistently with the MK 16 MOD 1 schedules, but total stop time differences between the 3RUTSB-he8n25 SS $He\text{-}O_2$ and MK 16 MOD 1 schedules appear untenably large.

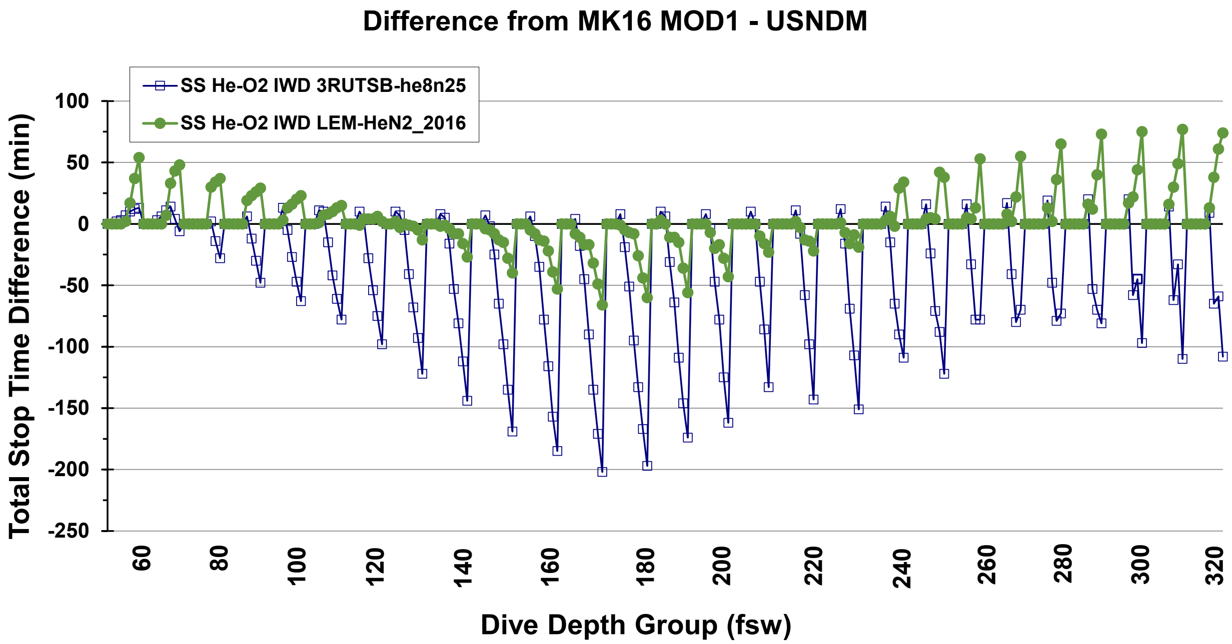

Figure 13. Differences in total in-water decompression stop times of candidate SS He-O_2 decompression schedules produced with different models from total decompression stop times of corresponding schedules in the current USN MK 16 MOD 1 constant 1.3 atm PO_2-in-He table. Schedules are ordered by increasing bottom times in groups of increasing dive depth (fsw). Positive differences indicate longer SS He-O_2 decompressions than corresponding MK 16 MOD 1 decompressions. Lines between points are shown for clarity only.

SurDO_2

There are no reliable means to estimate DCS risks of SS He-O_2 SurDO_2 schedules, where risk accumulated during surface intervals can contribute substantially, and perhaps inappropriately, to the overall estimate. For instance, LEM models cannot account for any latency in the accumulation of DCS risk after decompression. Instantaneous DCS risk in such models is consequently highest immediately after surfacing, which causes contributions of risk accumulated during surface intervals before chamber recompression for SurDO_2 to be inappropriately high. 3RUT gas and bubble dynamics models more typically predict slow onset of DCS risk after decompression and lower risks during surface intervals, but confidence in the quantitative predictions of the present 3RUTSB-he8n25 model is low. Notably, present SS He-O_2 procedures recommend administration of DCS treatment in lieu of continuing SurD if Type II DCS occurs during the surface interval or Type I DCS occurs during the surface interval and fails to resolve within 15 minutes of completing compression to the 50 fsw first SurDO_2 stop. The conditional risk of DCS computed under the condition that

DCS has not occurred by the end of the time at surface in a surface interval[e] is thus of principal interest as the only risk that remains to be endured in any decompression that proceeds into SurD. Such risk is based only on the risk accrued after the end of the time at surface and represents an estimate of only the in-chamber and post surfacing phases of a SurD procedure.

Conditional risks of DCS during and after the in-chamber phases of SurD were computed in accord with SurD procedures for SS He-O_2 decompressions in the current *U.S. Navy Diving Manual*. Surface intervals as defined operationally in footnote (e) below were assumed to be 5 minutes in duration. After compression on air to the first chamber stop at 50 fsw, the diver was assumed to be breathing 85% O_2-in-N_2 from a chamber built-in-breathing system (BIBS), typical of divers in an air atmosphere breathing 100% O_2 by mask. The first chamber O_2 period consisted of 15 minutes on O_2 at 50 fsw followed by 15 minutes on oxygen at 40 fsw. Up to three of the ensuing O_2 breathing periods were completed at 40 fsw. The schedules included the recommended 5-minute air-breathing break after each 30 minutes of O_2 breathing in the chamber except after the last O_2 period before surfacing on air. If more than four chamber O_2 periods were required by the schedule, remaining O_2 periods were completed at 30 fsw after the chamber was decompressed to 30 fsw during the air break following the fourth O_2 period.

Results illustrated in Figure 14 indicate that if a decompression proceeds into SurD, the ensuing risk of DCS remains acceptable. The upper and lower 95% confidence intervals of the estimated conditional probabilities either span the 2.3% target risk or are below that target risk with 7 exceptions in which the low 95% confidence limit exceeds 2.3% but is still less than 2.9%.

[e] A surface interval is operationally defined as the period between the time leaving the 40 fsw last in-water stop to the time of arrival at the 50 fsw first chamber stop. Conditional probabilities of DCS during and after SurD were computed from the risks of DCS accrued after completion of the time at surface in a surface interval.

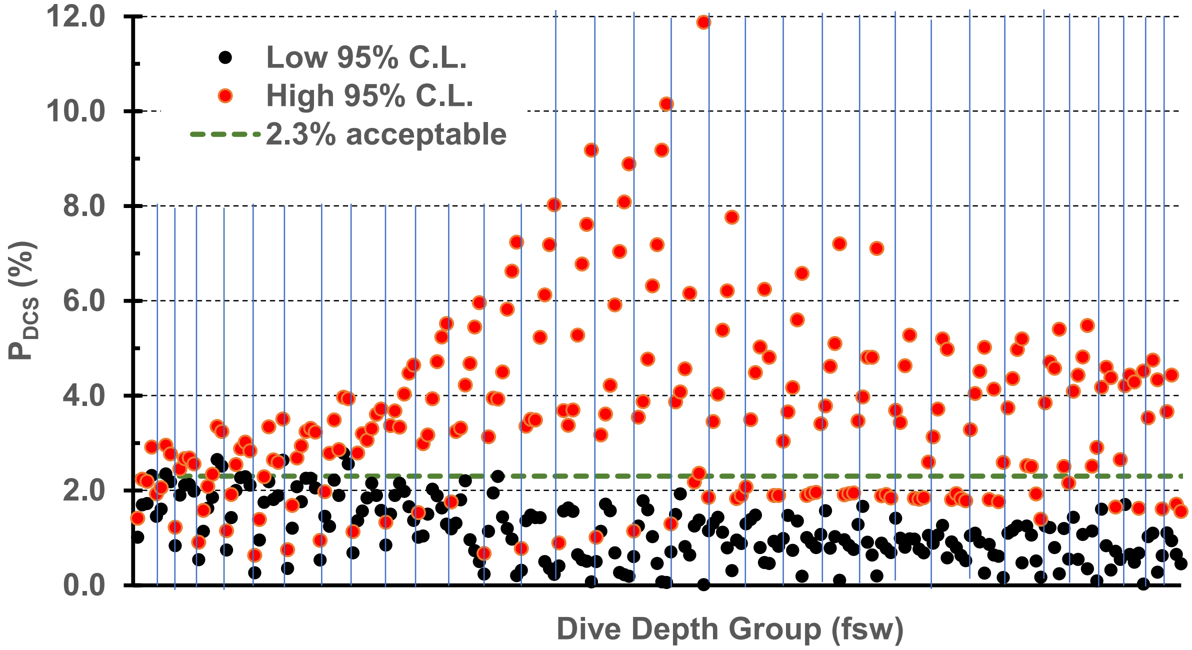

Figure 14. LEM-N2He_2016 – 95% upper and lower confidence limits of estimated conditional risks of DCS during in-chamber and post-surfacing phases of the 224 SurDO2 schedules in the initial candidate replacement table (Appendix D). Lower and upper limit pairs are shown for schedules with increasing bottom times in groups of increasing dive depth separated by vertical lines. Labeling of the dive depth groups is unnecessary to appreciate that the confidence limits of the estimated risks are either comfortably below or span the 2.3% acceptable risk with only 7 exceptions.

Revised LEM-HeN2_2016 Decompression Table

Schedules at each dive depth in the current SS He-O_2 Decompression Table incorporated conservatism from roundup provisions in its precursor 1991 Minimum/Maximum Percent Oxygen Table. These provisions obviated need to compensate further for the ±0.5% gas mixing error allowed elsewhere in the Diving Manual. However, such conservatism was not built into the initial candidate replacement SS He-O_2 tables. As the LEM-HeN2_2016 table was emerging as the preferred replacement for the current SS He-O_2 table, the LEM-HeN2_2016 table was revised to accommodate this mixing error. The revised table is given in Appendix E with schedules computed assuming divers breathe the minimum bottom gas oxygen fractions in Table 3. The schedules were computed as before to incur a 2.3% acceptable risk of DCS. Stop times for all stops except the first in a schedule and stops with a gas switch included travel time from the preceding stop. The influence of the revisions on total decompression stop times and numbers of SurDO2 periods is illustrated in Figures 15 and 16.

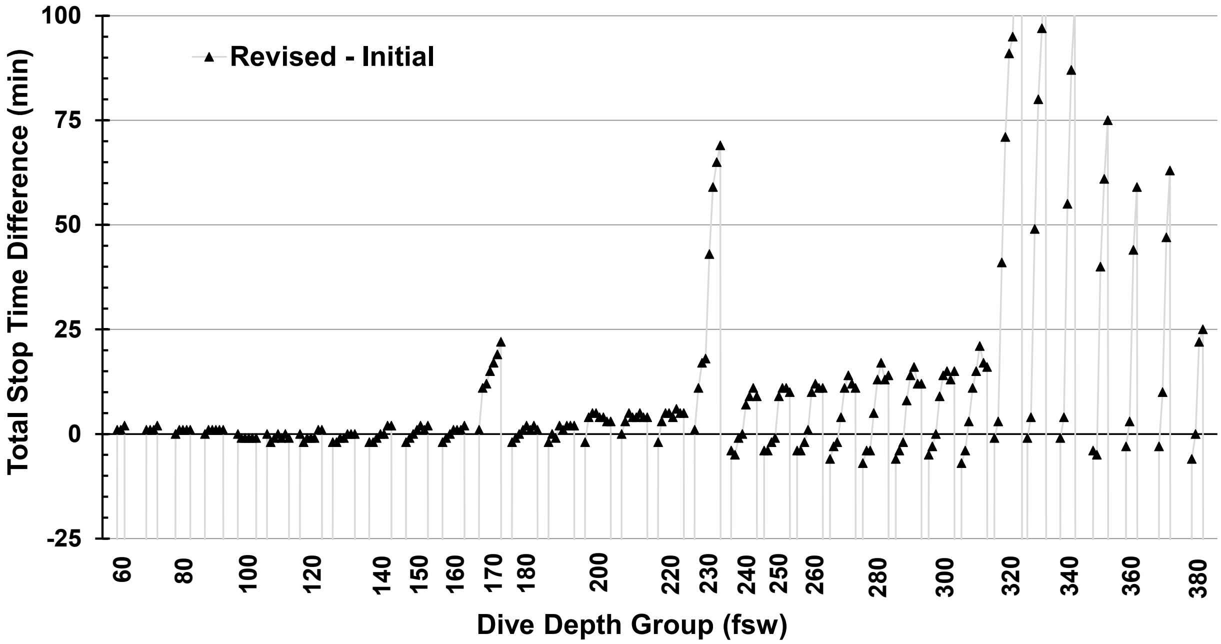

Figure 15. Differences in total decompression stop times between revised and initial candidate LEM-HeN2_2016 in-water SS He-O_2 replacement schedules. The differences for the schedules at each dive depth are represented by filled triangles, ordered by increasing bottom times in groups of increasing dive depth (fsw). Positive differences indicate longer decompressions in the revised schedules than in the initial schedules. Stop times are appreciably increased only for those dives in depth groups for which the minimum FO_2 has been decreased to that for the next lower FO_2 gas mix. Lines between points are shown for clarity only.

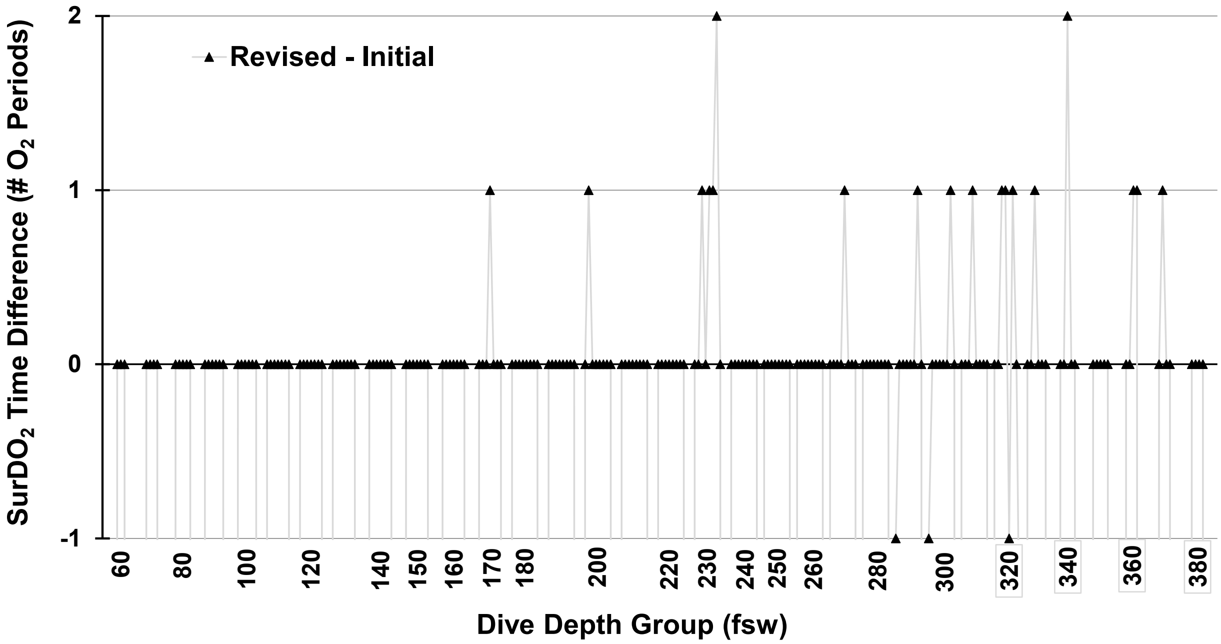

Figure 16. Difference between the number of SurDO$_2$ chamber periods in revised and initial candidate LEM-HeN2_2016 SS He-O$_2$ replacement schedules. The differences for the schedules at each dive depth are represented by filled triangles, ordered by increasing bottom times in groups of increasing dive depth. The number of SurDO$_2$ O$_2$ periods remains unchanged for most schedules, except those in the 170, 230, 320 fsw and deeper dive depth groups. Lines between points are shown for clarity only.

Application

Tabulated schedules were computed with a gas switch to 50% He/50% O$_2$ at the first decompression stop at or shallower than 90 fsw and deeper than 30 fsw. An earlier NEDU study provided evidence that breathing nitrox instead of heliox during heliox decompression stops does not increase the overall P_{DCS} compared to breathing heliox throughout the stops.[23,24] Moreover, laboratory chamber man-dive data suggests that DCS occurrence after a heliox-to-nitrox breathing gas switch is more likely to manifest as Type I DCS rather than Type II DCS.[25] This indication is consistent with the results from another more exhaustive review of man-dive data showing that Type II DCS incidence is greater than Type I DCS after dives in which only heliox is breathed than after dives in which only nitrox is breathed.[26] Accordingly, and to take advantage of the lower cost and greater availability of nitrogen, switch to a 50% N$_2$/50% O$_2$ inspired gas in place of 50% He/50% O$_2$ is recommended. LEM-N2He_2016 model estimates of P_{DCS} for LEM-N2He_2016 in-water decompression (IWD) schedules in Appendix D executed in accord with this recommendation are indistinguishable from 2.3% within the 95% confidence limits of the estimates or exceed 2.3% by usually less than 0.5%. LEM-N2He_2016 model estimates of conditional risks of SurDO$_2$ schedules in Appendix D executed in accord with this recommendation are also uniformly indistinguishable from

2.3% within the 95% confidence limits of the estimates. To benefit the diver, the switch should be made as the diver passes through 90 fsw during ascent, even in schedules that do not have a 90 fsw stop. The diver's UBA should then be ventilated at the next prescribed stop.

$SurDO_2$ may be commenced as prescribed in the current SS He-O_2 procedures upon completion of the 40 fsw in-water stop. If no 40 fsw stop is prescribed, completion of a 5-minute stop at 40 fsw is recommended after ascent to 40 fsw from the last tabulated stop and before commencing SurD.

SUMMARY AND CONCLUSIONS

A 3RUTSB model, 3RUTSB-he8n25, was fit to the legacy he8n25 training data used to develop the current 1.3 atm constant PO_2-in-He decompression table for MK16 MOD 1 UBA diving. The he8n25 data was augmented with additional data representative of surface-supplied He-O_2 diving operations in an expanded compilation of data, HeN2_2016. Fit of a 3RUTSB model to this expanded data was precluded by excessively long computation times required to solve 3RUTSB models on SS He-O_2 diving profiles. However, a linear-exponential multi-gas model, LEM-HeN2_2016, similar to the LEM-he8n25 model used to compute the current 1.3 atm constant PO_2-in-He decompression table for MK16 MOD 1 UBA diving, was successfully fit to this data. Neither the 3RUTSB-he8n25 or LEM-HeN2_2016 model passed a global chi-square test of goodness-of-fit to its respective training data, but each provided improved fits to constant O_2 fraction heliox dives and worsened fits to constant O_2 partial pressure heliox dives compared to LEM-he8n2 legacy model performance. Overall, LEM-HeN2_2016 performance on heliox dives of most types in HeN2_2016 was superior to that of 3RUTSB-he8n25, and was only marginally worse on the DC8416W data most closely representative of SS He-O_2 diving. Without clear statistical justification for selection of either model over the other for computation of a replacement SS He-O_2 decompression table, candidate replacement tables were computed with each of the models and compared for features that would motivate selection of one table over the other to recommend for man-testing.

3RUTSB-he8n25 schedules for longer deep dives were substantially shorter than LEM-HeN2_2016 schedules, with a marked skew of decompression stop times to deep stops typical of schedules prescribed by gas and bubble dynamics models. While these short decompressions are attractive as replacements for the current SS He-O2 schedules, a hypothetical advantage of a deep stop skew under another gas and bubble dynamics model was not confirmed in man-tests of decompressions from a 170 fsw/30 min air dive with such deep stops.[22] The deep stop skew of stop times in the 3RUTSB schedules was also accompanied by relatively short 30 and 20 fsw in-water stops which caused the number of chamber O_2 periods for SurD in the 3RUTSB-he8n25 schedules to be fewer than in the LEM-HeN2_2016 schedules. The long in-water decompression times in these 3RUTSB-he8n25 schedules are consequently considerably less attractive than the longer $SurDO_2$ times in the LEM-HeN2_2016 schedules. Finally, 3RUTSB-he8n25 schedules for longer deeper SS $He-O_2$ dives also appeared untenably short compared to corresponding 1.3 atm PO_2-in-He MK 16 MOD 1 schedules in the current *U.S. Navy Diving Manual*.

In conclusion, a table of LEM-HeN2_2016 SS $He-O_2$ decompression schedules modified in Appendix E to accommodate a ±0.5% gas mixing error allowed in the *U.S. Navy Diving Manual* is recommended as the best candidate to replace the current U.S. Navy SS $He-O_2$ decompression table. Man-testing of representative schedules in the recommended replacement table completed to establish that they incur acceptable risks of DCS is described in a follow-on report.[27]

Surface-supplied $He-O_2$ bounce diving to depths in excess of 300 fsw requires inordinately long decompressions to keep estimated risks of DCS within acceptable limits and is not recommended.

ACKNOWLEDGEMENTS

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Appendix A. 3RUTSB-he8n25 Probabilistic Model Parameters

Type*	Value	Parameter
F	4.70000E+01	PH_20 (mm-Hg)
F	1.00000E+00	Respiratory Quotient.
F	4.50000E+01	Tissue PCO_2 (mm-Hg); all tissues.
F	2.50000E+01	Tissue PO_2 (mm-Hg); all tissues. (Fixed, in PTMG)
A	4.23339E-01	Gain/10**3, tis 1
A	7.02336E-02	Gain/10**3, tis 2
A	8.75226E-02	Gain/10**3, tis 3
F	2.35600E-02	O_2 solubility in blood
F	1.41000E-02	N_2 solubility in blood
F	1.04000E-02	He solubility in blood
F	1.00000E+00	Total # bubble nuclei (N0), tis 1
F	1.00000E+00	Total # bubble nuclei (N0), tis 2
F	1.00000E+00	Total # bubble nuclei (N0), tis 3
A	5.85543E+05	elastic modulus (atm/V), tis 1 [scaled]
A	1.16596E+05	elastic modulus (atm/V), tis 2 [scaled]
A	8.67172E+04	elastic modulus (atm/V), tis 3 [scaled]
A	1.03765E-03	r00(t); nucleonic or min bubble radius (cm), tis 1 [scaled]
A	9.21010E-03	r00(t); nucleonic or min bubble radius (cm), tis 2 [scaled]
A	2.13014E-04	r00(t); nucleonic or min bubble radius (cm), tis 3 [scaled]
F	6.12395E-03	O_2 solubility in tissue 1; [ml(SPD,37)/ml/atm]
A	2.98415E-03	N_2 solubility in tissue 1; [ml(SPD,37)/ml/atm]
A	4.76309E-04	He solubility in tissue 1; [ml(SPD,37)/ml/atm]
F	9.01281E-05	O_2 solubility in tissue 2; [ml(SPD,37)/ml/atm]
A	3.85049E-05	N_2 solubility in tissue 2; [ml(SPD,37)/ml/atm]
A	2.68939E-05	He solubility in tissue 2; [ml(SPD,37)/ml/atm]
F	2.71977E-05	O_2 solubility in tissue 1; [ml(SPD,37)/ml/atm]
A	4.66312E-05	N_2 solubility in tissue 3; [ml(SPD,37)/ml/atm]
A	2.97505E-04	He solubility in tissue 3; [ml(SPD,37)/ml/atm]
A	1.00000E+05	tissue 1 volume (ml), [scaled]
A	5.19017E-02	tissue 2 volume (ml), [scaled]
A	1.00000E+05	tissue 3 volume (ml), [scaled]
A	4.85445E-04	Qdot*k/V; tis 1
A	4.91970E-05	Qdot*k/V; tis 2
A	1.72054E-03	Qdot*k/V; tis 3
F	5.97848E-05	O_2 diffusivity [cm**2/min], tis 1 [scaled]
A	9.21929E-04	N_2 diffusivity [cm**2/min], tis 1 [scaled]
A	2.02327E-05	He diffusivity [cm**2/min], tis 1 [scaled]
F	1.01851E-02	O_2 diffusivity [cm**2/min], tis 2 [scaled]

A	4.90803E-03	N_2 diffusivity [cm**2/min], tis 2 [scaled]
A	9.64330E+01	He diffusivity [cm**2/min], tis 2 [scaled]
F	1.00000E+02	O_2 diffusivity [cm**2/min], tis 3 [scaled]
A	1.46269E+01	N_2 diffusivity [cm**2/min], tis 3 [scaled]
A	1.02774E-01	He diffusivity [cm**2/min], tis 3 [scaled]
F	1.00000E+00	BNPWR; bubble number power factor, tis 1
F	1.00000E+00	BNPWR; bubble number power factor, tis 2
F	1.00000E+00	BNPWR; bubble number power factor, tis 3
3	-1.23659E+03	Model log likelihood

* A ≡ adjustable parameter
  F ≡ fixed parameter

Integration control parameters:
  5.0000E-05 dTi; integration step size, minutes (as fit)
  5.0000E-04 dTi; integration step size, minutes (as applied)
Other model constants:
  3.0000E+01 sigma; surface tension, dyne/cm

# Profiles in dataset	1347
Total # individual trials	4669
Total # DCS marginals	118
Total # DCS positives	242
Overall DCS incidence (%)	5.436

Tissue	Gas	Half-time (min)	Bbbl rmin (cm)	Sigma (dyne/cm)
1	O_2	371.14316	1.04E-03	30
	N_2	302.19423		
	He	65.39437		
2	O_2	53.89790	9.21E-03	30
	N_2	38.47546		
	He	36.43413		
3	O_2	0.46507	2.13E-04	30
	N_2	1.33235		
	He	11.52448		

Parameter Covariance in Scaled 3RUT Models

Equations that describe the time courses of gas bubble evolution and gas exchange between blood, bubbles, and tissue in each compartment of the 3RUT models contain a term Λ with dimension 1/bubble radius r representing the effects of perfusion heterogeneity and bubble-bubble interactions on compartmental gas and bubble dynamics. In the scaled version of the 3RUT model used in present work, Λ is eliminated from these equations by substituting a nondimensionalized compartmental bubble radius $r' = \Lambda r$ for r throughout, where the prime denotes a value scaled by the compartmental Λ. The following model independent compartmental parameters then assume corresponding scaled values:

$\sigma' = \Lambda\sigma,$
$M' = M/\Lambda^3,$
$D' = D\Lambda^2,$
$V_t' = \Lambda^3 V_t,$
$V_b' = \Lambda^3 V_b = (4\pi/3)(r')^3.$

Note that the scaled surface tension σ' and elastic modulus M' have the dimensions of pressure, and the scaled gas diffusivities D', tissue volumes V_t', and bubble volumes V_b' are dimensionless.

In present work, the independent parameters adjusted in the model optimization processes were the scaled forms, lumped with a shared, but indeterminate Λ. As a result, covariance of the parameters may have contributed to the tendency of the processes to iterate interminably without converging on a final optimal parameter set. It remains to be determined in future work whether consideration of the Λ's as separate independent variables from the unscaled parameters improves the ability to optimize these models.

Appendix B. LEM-HeN2_2016 Probabilistic Model Parameters

Parameter #	Type*	Value	Description
4	F	0.0000000000E+00	PTH_2O
5	F	1.0000000000E+00	Respiratory Quotient.
6	F	0.0000000000E+00	$PTCO_2$=$PVCO_2$; Tissue PCO_2 == Venous PCO_2 (mm-Hg).
7	F	0.0000000000E+00	PTO_2=PVO_2; Tissue PO_2 == Venous PO_2 (mm-Hg).
8	F	0.0000000000E+00	$PACO_2$; Arterial PCO_2 (mm-Hg).
10	A	1.1470964203E-06	Gain/10**3 [/min], tis 1
11	A	2.1611214333E-05	Gain/10**3 [/min], tis 2
12	A	5.4271127761E-07	Gain/10**3 [/min], tis 3
60	F	9.9000000000E+01	PSET, O_2 tracking threshold, (ATA), tis 1
61	A	9.5472914101E-01	PSET, O_2 tracking threshold, (ATA), tis 2
62	F	9.9000000000E+01	PSET, O_2 tracking threshold, (ATA), tis 3
70	F	1.0000000000E+00	TC(t); O_2 exchange time constant [min], tis 1
71	A	7.1066028539E+00	TC(t); N_2 exchange time constant [min], tis 1
72	A	1.4891046457E+01	TC(t); He exchange time constant [min], tis 1
73	A	2.0606789498E+01	TC(t); O_2 exchange time constant [min], tis 2
74	A	5.1188690508E+01	TC(t); N_2 exchange time constant [min], tis 2
75	A	3.0855198631E+01	TC(t); He exchange time constant [min], tis 2
76	F	1.0000000000E+00	TC(t); O_2 exchange time constant [min], tis 3
77	A	2.6772472105E+02	TC(t); N_2 exchange time constant [min], tis 3
78	A	2.7690139813E+02	TC(t); He exchange time constant [min], tis 3
80	A	4.5314588828E-01	PXO(t); E->L kinetic threshold (atm), tissue 1
81	F	-2.7109000000E-02	PXO(t); E->L kinetic threshold (atm), tissue 2
82	F	9.9999999999E+09	PXO(t); E->L kinetic threshold (atm), tissue 3
90	F	7.8779000000E-01	THR(t); risk threshold [atm], in tissue 1
91	F	1.9786000000E+00	THR(t); risk threshold [atm], in tissue 2
92	A	-1.5640353796E-01	THR(t); risk threshold [atm], in tissue 3
99	3	-1.8232876231E+03	Model log likelihood

* A ≡ adjustable parameter
F ≡ fixed parameter

Integration Control Parameters

Value	Description
1.5000E-02	dTiMn; Minimum time step (Max resolution, minutes)
3.0000E-01	dTiMx; Maximum time step (Min resolution, minutes)
9.0000E-01	dTiK ; half-dr/dt value (cm/min) for time step decay

# Profiles in dataset	2943
Total # individual trials	7683
Total # DCS marginals	88
Total # DCS positives	340
Overall DCS incidence (%)	4.54

c-index = 0.6655313

Tissue	Gas	Half-time (min)
1	O_2	0.69315
	N_2	4.92592
	He	10.32169
2	O_2	14.28354
	N_2	35.48130
	He	21.38719
3	O_2	0.69315
	N_2	185.57264
	He	191.93342

Parameter #	Value	+/- Std Erro	Coeff. of Variation
10	1.1470964203E-06	2.8897070473E-07	2.5191492154E-01
11	2.1611214333E-05	6.5505258798E-06	3.0310771894E-01
12	5.4271127761E-07	3.5022284062E-08	6.4532073511E-02
61	9.5472914101E-01	2.0114666124E-02	2.1068453093E-02
71	7.1066028539E+00	2.0925040814E-01	2.9444505686E-02
72	1.4891046457E+01	1.7246067246E+00	1.1581501203E-01
73	2.0606789498E+01	3.3114947520E-01	1.6069920801E-02
74	5.1188690508E+01	4.7983602960E+00	9.3738680329E-02
75	3.0855198631E+01	1.5427175691E+00	4.9998627057E-02
77	2.6772472105E+02	5.6867988540E+00	2.1241216843E-02
78	2.7690139813E+02	7.0897420650E+00	2.5603850731E-02
80	4.5314588828E-01	1.2376696895E-01	2.7312830624E-01
92	-1.5640353796E-01	3.6742541723E-03	-2.3492142315E-02

Appendix C. 3RUTSB-he8n25 Candidate Replacement Surface-Supplied Helium-Oxygen Decompression Table

Schedules in Table C-1 were computed with the 3RUTSB-he8n25 model to incur an estimated risk of DCS no higher than 2.3% assuming divers breathe the minimum bottom gas O_2 fraction given for each dive depth group in Table 2.

Assumed 75 fpm descent rate and 30 fpm ascent rate.

Times at all stops except the first include travel time to the stop.

Tabulated in-water stop times at 30 and 20 fsw do not include a recommended 5-minute air-breathing break after each 30 minutes of O_2 breathing. Times at these stops were computed assuming a conservative diver-inspired O_2 fraction of 90%, while delivery of 100% O_2 is recommended during these periods in normal operations.

A double line in a dive depth group separates normal exposure dives above the line from exceptional exposure dives below the line as given for the group in the current U.S. Navy Surface-Supplied Helium-Oxygen Decompression Table.

Table C-1. 3RUTSB-he8n25 Candidate Replacement Surface-Supplied Helium-Oxygen Decompression Table

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 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
60	10																				0	
Max O_2 = 40.0%	20																				0	
Min O_2 = 21.0%	30																		2		2	1
	40																		3		3	1
	60																		7		7	1
	80																		10		10	1
	100																		12		12	1
	120																		13		13	1
70	10																				0	
Max O_2 = 40.0%	20																				0	
Min O_2 = 21.0%	30																		3		3	1
	40																		6		6	1
	60																		11		11	1
	80																		14		14	1
	100														1				15		16	1
	120																1	4	15		20	1
80	10																				0	
Max O_2 = 38.0%	20																		3		3	1
Min O_2 = 21.0%	30																		6		6	1
	40													1					8		9	1
	60													1					14		15	1
	80																4		17		21	1
	100																4	6	15		25	1
	120																4	8	16		28	1

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	
	20																		3		3	1
Max O_2 = 34.9%	30												1						7		8	1
Min O_2 = 21.0%	40												1						11		12	1
	60															2			19		21	1
	80																11		18		29	1
	100															3	4	11	15		33	1
	120															3	7	9	15		34	1
100	10																				0	
Max O_2 = 32.3%	20												1						6		7	1
Min O_2 = 21.0%	30												1						12		13	1
	40												1						16		17	1
	60														1	4	6		17		28	1
	80														2	4	4	9	16		35	1
	100														2	4	8	10	14		38	1
	120														2	4	12	12	12		42	1
110	10																				0	
Max O_2 = 30%	20												1						8		9	1
Min O_2 = 21.0%	30												1						14		15	1
	40												1						19		20	1
	60															6	10		19		35	1
	80													1	3	4	7	11	14		40	1
	100													4		6	11	13	12		46	1
	120													1	13	4	9	12	13		52	1

Depth	Bottom	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN). All except first and those with a gas switch include travel time to stop																			TOTAL IWD STOP	Chamber
(fswg)	Time (min)	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	TIME	O_2
FO_2 %		BOTTOM MIX											(50)	(50)	(50)	(50)	(50)	(50)	(100)	(100)	(min)	Periods
120	10																				0	
Max O_2 = 28%	20												1						10		11	1
Min O_2 = 21.0%	30												1						17		18	1
	40														5	3			18		26	1
	60													3	3	4	4	10	15		39	1
	80													3	3	10	6	13	13		48	1
	100												3		8	6	11	13	14		55	1
	120													5	4	11	12	12	17		61	1
130	10																				0	
Max O_2 = 26.3%	20												1						12		13	1
Min O_2 = 21.0%	30												1						19		20	1
	40													2	3	7			20		32	1
	60												2	3	3	4	7	11	14		44	1
	80												2	3	7	8	13	9	12		54	1
	100												3	3	15	3	12	11	16		63	1
	120													15	1	14	10	11	18		69	1
140	10																		5		5	1
Max O_2 = 24.8%	20												1						14		15	1
Min O_2 = 21.0%	30													3					21		24	1
	40													7	1	5	2	6	15		36	1
	60														10	7	6	8	20		51	1
	80												4	5	4	9	12	11	17		62	1
	100												5	10	5	9	11	13	18		71	1
	120												12	13		14	21		19		79	1

Depth (fswg) FO2 %	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 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
150	10																		5		5	1
Max O_2 = 23.4%	20												1						16		17	1
Min O_2 = 21.0%	30													5	2	4			18		29	1
	40													7	6	2	2	8	16		41	1
	60													7	4	6	11	11	14	4	57	1
	80												9	1	9	10	10	13	17		69	1
	100												8	22		7	11	12	19		79	1
	120												24	12		12	6	12	20		86	1
160	10												1						6		7	1
Max O_2 = 22.2%	20												1						18		19	1
Min O_2 = 21.0%	30												2	3	3	4	5		16		33	1
	40															9	6	9	18	4	46	1
	60												9	5		9	12	9	18		62	1
	80												10	8	15	1	11	13	18		76	1
	100												17	15		9	12	12	22		87	1
	120												26	8	10	10	12	12	25		103	1
170	10												1						6		7	1
Max O_2 = 21.2%	20												1						20		21	1
Min O_2 = 21.0%	30												4	4	4	3	3	5	14		37	1
	40															15	5	11	17	3	51	1
	60												12	2	7	7	11	13	17		69	1
	80												13	14	1	10	11	13	23		85	1
	100												28	19	9	12	8	8	18		102	1
	120									5	5	3	26	10	8	11	24		28		120	1

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 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
180	10												1						9		10	1
Max O_2 = 20.1%	20												2	3					23		28	1
Min O_2 = 16.0%	30															14	4	10	12	9	49	1
	40												10	8	2		12	10	19		61	1
	60												18		21		11	12	24		86	1
	80												40	13	17	5	11	10	19		115	1
	100												85		6	7	12	12	16		138	1
	120							5	7	12			61	9	9	10	24		23		160	1
190	10												1						11		12	1
Max O_2 = 19.2%	20												1	3	7				21		32	1
Min O_2 = 16.0%	30														13	2	8	10	13	7	53	1
	40												14	4	2	5	11	13	17		66	1
	60												19	7	22		11	11	27		97	1
	80												56	9	15	8	10	12	21		131	1
	100												107		13		23		21		164	1
	120						4	6	9	12			68	13	7	8	12	12	23		174	1
200	10												1						12		13	1
Max O_2 = 18.4%	20												6	4	2	5			19		36	1
Min O_2 = 16.0%	30													7	11		10	10	10	9	57	1
	40												18	2	1	15	8	10	19		73	1
	60												31	9	21	1	11	11	27		111	1
	80												72	9	17	15	7	8	20		148	1
	100							16	5	15			64	13	5	10	11	9	29		177	1
	120							14	14	8			80	4	8	10	22		31		191	2

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 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
210	10												1						14		15	1
Max O_2 = 17.7%	20												9	3	2	2	7		17		40	1
Min O_2 = 16.0%	30												2	15	3	2	8	11	16	3	60	1
	40												20	1	1	18	4	13	23		80	1
	60												45	9	24	17	8		25		128	1
	80												91	6	17	14	16		25		169	1
	100						10	7	13	8			84	3	7	12	9	11	27		191	1
	120						11	12	16				92	8	6	8	24		30		207	2
220	10												1						15		16	1
Max O_2 = 17.0%	20												11	3		5	3	5	16		43	1
Min O_2 = 16.0%	30												15	3	5	1	11	12	18		65	1
	40												21	1	4	22		10	30		88	2
	60												59	9	19	20	8		29		144	1
	80				5	3	7	11	6	10			72	7	8	11	13	6	28		187	1
	100					5	15	5	18	6			90	6	6	9	9	10	27		206	1
	120					13	7	16	18	6			87	8	6	9	8	8	35		221	2
230	10												1						17		18	1
Max O_2 = 16.3%	20												12	3	3		3	9	16		46	1
Min O_2 = 16.0%	30												20	1	1	4	11	13	20		70	1
	40												23		11	24	3		38		99	2
	60												73	9	9	34			38		163	2
	80			2	1	14	5	2	16	8			75	8	8	10	25		27		201	1
	100			5	5	3	8	17	14				101	3	10	10	7	12	26		221	1
	120				8	9	14	16	14				110	6	9	3	17		32		238	2

Depth (fswg) FO₂ %	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)		
240	10												1						21		22	1
Max O_2 = 15.7%	20												14	5	2	1	6	8	21		57	1
Min O_2 = 12.0%	30												23	1	1	16	6	7	37		91	2
	40												34	9	14	25			55		137	2
	60				24	12	1	11	11				100	7	7	9	10	9	32		233	2
	80	1	7	18		4	17	19		1			122	4	6	12	18		34		263	2
	100	5	10	1	14	14	20	21	9				127	3	6	5	12		38		285	2
	120	6	4	11	15	19	20	21	9				135	1	26				35		302	2
250	10												2						20	3	25	1
Max O_2 = 15.2%	20												16	5	1	1	7	10	20		60	1
Min O_2 = 12.0%	30												24	2		28			47		101	2
	40												46	9	9	32			64		160	3
	60			13	13	13		13	15				109	5	4	9	17		37		248	2
	80		16	2	14	7	18	19		1			132	11	5	18			38		281	2
	100	8	8	12	9	19	20	17		2			134	10	22				44		305	2
	120	12	5	13	18	20	20	17		2			144	25					48		324	2
260	10												2	3					22		27	1
Max O_2 = 14.6%	20												17	6			10	11	19		63	1
Min O_2 = 12.0%	30												25	1	2	27			57		112	2
	40												58	9	9	35			81		192	3
	60		23	1	6	6	11	19	11				118	5	5	5	16		37		263	2
	80		14	15	6	12	20	21	10				139	3	4	7	3		43		297	2
	100	14	11	6	17	20	20	17		2			144	16	8				47		322	2
	120	18	7	17	18	19	21	21	10				160						50		341	2

Depth (fswg) FO₂ %	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)		
270	10												4	4					22		30	1
Max O_2 = 14.2%	20												20	3	1	1	10	13	20		68	1
Min O_2 = 12.0%	30												26	1	7	29			64		127	3
	40	1	2	1	3	4	22						88	2	20	26			54		223	2
	60	10	21	2	4	5	17	19		1			129	3	10	7	15		36		279	2
	80	18	9	8	8	19	20	17		2			143	8	17				45		314	2
	100	26	2	13	19	20	20	21	10				158						51		340	2
	120	21	13	18	18	19	20	22	11				163						55		360	2
280	10												6	3	4				20		33	1
Max O_2 = 13.7%	20												22	1	1	3	11	12	24		74	1
Min O_2 = 12.0%	30												27	7	9	31			72		146	3
	40		6	18			12	12	12				132		3		11		37		243	2
	60	16	2	19	8	3	19	21	11				137	3	7	7			44		297	2
	80	25	10	3	15	20	20	18		3			161	10					49		334	2
	100	30	4	16	21	18	20	21	11				162						59		362	2
	120	48	19	18	18	20	20	21	13				167						57		401	2
290	10												4	6	3	2	2		19		36	1
Max O_2 = 13.3%	20												23		2	4	19	4	29		81	1
Min O_2 = 12.0%	30												35	9	9	34			86		173	3
	40			6	33		7		6				108	60					39		259	2
	60	19	1	18	12	5	20	21	12				158						49		315	2
	80	30	8	5	18	20	20	22	12				161						57		353	2
	100	33	14	18	19	20	20	21	13				166						64		388	3
	120	85	18	18	19	19	20	22	15		1		166						64		447	3

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)		
300	10												6	3	9				22		40	1
Max O_2 = 12.9%	20												23	1	2	13	13		37		89	2
Min O_2 = 12.0%	30												45	8	10	41			114		218	4
	40	21	3	10	4	11	5	15	12				117	6	8	5	9	3	39		268	2
	60	23	15	7	3	17	22	20	12				159						54		332	2
	80	37	1	12	20	19	20	21	14		1		166						64		375	3
	100	64	17	19	18	19	20	22	17		1		167						73		437	3
	120	121	18	18	18	19	21	23	22		2		175						80		517	3
310	10												8	6	3	2	1	6	15		41	1
Max O_2 = 12.5%	20												25	1		11	12		49		98	2
Min O_2 = 12.0%	30			3	10	26		13	6				77	62					52		249	2
	40	27		4	10	14		21	12				123	3	13	10			44		281	2
	60	34	7	5	8	20	20	22	16		1		164						63		360	3
	80	40	1	16	21	18	21	21	16		2		168						77		401	3
	100	99	17	18	18	20	20	22	25	8			161						84		492	3
	120	157	17	18	18	20	22	20	22	13			179						70		556	3
320	10												9	8		2	5	4	16		44	1
Max O_2 = 12.2%	20												26	1		17	6		59		109	2
Min O_2 = 12.0%	30	6	6	12			24						94	50		8			43		243	2
	40	34	2	6	3	13	9	22	14				158						49		310	2
	60	40	2	5	14	19	20	21	16		2		166						71		376	3
	80	43	17	19	18	20	20	24	21	10			167						85		444	3
	100	133	17	18	19	19	20	22	24	15			190						75		552	3
	120	190	21	18	19	19	20	21	22	19			217						64		630	3

Depth (fswg) FO₂ %	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)		
330	10												9	4	3	9			23		48	1
Max O_2 = 11.8%	20												27	1	1	25			67		121	3
	30			6	7	26	13		13	14			91	65					30		265	2
	40	34	8	1	6	5	18	21	14				143	14					46		310	2
	60	43	3	2	18	23	20	21	22	9			161						81		403	3
	80	75	19	18	18	20	20	21	23	15			196						80		505	3
	100	165	23	18	18	20	20	21	23	23			248						54		633	2
	120	226	17	19	19	19	22	19	23	24	24	3	200	76					30		721	2
340	10												12	4	2		6		27		51	1
Max O_2 = 11.5%	20												27	2		29			77		135	3
	30	4	21	11	13		7	8	14				119	14	2	16			39		268	2
	40	36	5	9	1	8	20	21	14		1		159						55		329	2
	60	45	2	7	18	21	20	21	23	13			186						80		436	3
	80	103	30	44		20	20	21	22	22			249						58		589	2
	100	200	18	75	10	5	20	19	22	23	25	15	201	59			2		50	4	748	2
350	10												9	3	8	6		3	24		53	1
Max O_2 = 11.2%	20												29	2	5	35			96		167	4
	30	25	10	7	10	10	5	20	15				156						47		305	2
	40	40		10	15	8	22	22	18	1			220						28		384	1
	60	49	6	12	20	21	22	23	24	25	10		259						44		515	2

Depth (fswg) FO2 %	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)		
360	10												11	6	5		10		24		56	1
Max O_2 = 10.9%	20	3		1									36	9	9	37			108		203	4
	30	36	8	5	4	8	12	24	12				159						50		318	2
	40	42	10	5	3	19	24	23	25	12			175						80		418	3
370	10												7	15	4	1	1	12	20		60	1
Max O_2 = 10.6%	20	2		4	5	17	1						68	9	11	37			95		249	4
	30	40	5	6	5	7	16	25	14				163						55		336	2
	40	45	10		7	22	23	25	24	20	1		226						48		451	2

Appendix D. Initial LEM-HeN2_2016 Candidate Replacement Surface-Supplied Helium-Oxygen Decompression Table

Schedules in Table D-1 were computed with the LEM-HeN2_2016 model to incur an estimated risk of DCS no higher than 2.3% assuming divers breathe the minimum bottom gas O_2 fraction given for each dive depth group in Table 2.

Assumed 75 fpm descent rate and 30 fpm ascent rate.

Times at all decompression stops except the first include travel time to the stop.

Tabulated in-water stop times at 30 and 20 fsw do not include a recommended 5-minute air-breathing break after each 30 minutes of O_2 breathing. Times at these stops were computed assuming a conservative diver-inspired O_2 fraction of 90%, while delivery of 100% O_2 is recommended during these periods in normal operations.

A double line in a dive depth group separates normal exposure dives above the line from exceptional exposure dives below the line as given for the group in the current U.S. Navy Surface-Supplied Helium-Oxygen Decompression Table.

Table D-1. Initial LEM-HeN2_2016 Candidate Replacement Surface-Supplied Helium-Oxygen Decompression Table

Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN)																			TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		200	190	180	170	160	150	140	130	120	110	100	90 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
60	10																				0	
Max O_2 = 40.0%	20																				0	
Min O_2 = 21.0%	30																				0	
	40																				0	
	60																		2		2	1
	80																			17	17	1
	100																			37	37	2
	120																			54	54	2
70	10																				0	
Max O_2 = 40.0%	20																				0	
Min O_2 = 21.0%	30																				0	
	40																				0	
	60																		7		7	1
	80																			33	33	2
	100																			55	55	2
	120																			74	74	3
80	10																				0	
Max O_2 = 38.0%	20																				0	
Min O_2 = 21.0%	30																				0	
	40																		3		3	1
	60																		1	20	21	1
	80																		2	47	49	2
	100																		2	71	73	3
	120																		2	91	93	4

Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN)																			TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		200	190	180	170	160	150	140	130	120	110	100	90 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
90	10																				0	
Max O_2 = 34.9%	20																				0	
Min O_2 = 21.0%	30																		3		3	1
	40																		4		4	1
	60																		3	31	34	2
	80																		3	61	64	3
	100												1						3	85	89	3
	120												1						12	98	111	4
100	10																				0	
Max O_2 = 32.3%	20																				0	
Min O_2 = 21.0%	30																		4		4	1
	40												1						8		9	1
	60												1						5	42	48	2
	80												1						6	73	80	3
	100												1						8	98	107	4
	120												1						31	98	130	5
110	10																				0	
Max O_2 = 30%	20																		4		4	1
Min O_2 = 21.0%	30												1						6		7	1
	40												1						6	12	19	1
	60												1						7	52	60	2
	80												1						7	86	94	4
	100												1						23	98	122	5
	120												1						47	99	147	5

Depth (fswg) FO2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN)																			TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		200	190	180	170	160	150	140	130	120	110	100	90 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
120	10																				0	
Max O_2 = 28%	20																		4		4	1
Min O_2 = 21.0%	30												1						8		9	1
	40												1						7	21	29	1
	60												1						8	64	73	3
	80												1						8	99	108	4
	100															2			36	99	137	5
	120															2			61	99	162	6
130	10																				0	
Max O_2 = 26.3%	20												1						6		7	1
Min O_2 = 21.0%	30												1						11		12	1
	40												1						8	30	39	2
	60												1						9	76	86	3
	80												1						20	101	122	5
	100														1	3			49	99	152	5
	120														1	3			74	101	179	6
140	10																				0	
Max O_2 = 24.8%	20												1						6		7	1
Min O_2 = 21.0%	30												1						19		20	1
	40												1	1					10	38	50	2
	60														2	2			10	83	97	4
	80													1	2	3	2		30	98	136	5
	100													1	1	3	3	3	58	98	167	6
	120														2	3	2	5	84	100	196	7

Depth (fswg) FO$_2$ %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN)																			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)		
150	10																				0	
Max O_2 = 23.4%	20												1						7		8	1
Min O_2 = 21.0%	30												1						9	18	28	1
	40													1	2				8	48	59	2
	60												1		3	2	4		17	83	110	4
	80													1	3	2	3	8	37	98	152	5
	100													2	2	2	5	10	67	98	186	6
	120													2	2	2	6	10	91	102	215	7
160	10																				0	
Max O_2 = 22.2%	20												1						9		10	1
Min O_2 = 21.0%	30												1	1					10	25	37	2
	40												1	2	2				11	53	69	3
	60												1	2	3	2	2	9	15	92	126	4
	80												1	2	3	2	10	9	45	98	170	5
	100													3	2	5	11	9	75	100	205	6
	120												1	2	2	8	10	9	100	103	235	7
170	10																				0	
Max O_2 = 21.2%	20												1						10		11	1
Min O_2 = 21.0%	30												1	1	2				8	33	45	2
	40												1	1	3	4			16	55	80	3
	60												2	2	2	2	10	10	17	97	142	4
	80												2	3	4	8	10	9	53	99	188	6
	100												2	2	6	11	10	9	83	101	224	7
	120												2	3	7	11	10	9	108	106	256	8

Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN)																			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)		
180	10												1						6		7	1
Max O_2 = 20.1%	20												1	1					16	3	21	1
Min O_2 = 16.0%	30												2	4					10	49	65	2
	40												3	3	2	2	3	5	16	71	105	3
	60												5	2	3	9	11	9	35	99	173	5
	80												6	2	10	11	11	9	72	101	222	6
	100												6	6	12	10	10	9	102	106	261	7
	120												6	8	12	11	18		130	113	298	9
190	10												1						6		7	1
Max O_2 = 19.2%	20												1	1	2				23		27	1
Min O_2 = 16.0%	30												3	4					18	50	75	3
	40												5	2	2	3	4	10	15	78	119	4
	60												7	2	8	12	10	9	42	101	191	5
	80												7	11	12	10	9	9	80	103	241	7
	100												11	13	11	10	10	8	110	109	282	8
	120												14	12	11	10	18		137	117	319	9
200	10												1						6		7	1
Max O_2 = 18.4%	20												1	2	2				8	21	34	1
Min O_2 = 16.0%	30												4	2	3	2	3	2	16	52	84	3
	40												6	2	3	3	11	9	15	85	134	4
	60												8	8	12	10	10	9	50	101	208	6
	80												17	12	11	10	9	9	88	105	261	7
	100								3	3	1		18	12	11	10	10	7	123	112	310	8
	120								3	4	3		18	12	10	11	17		150	123	351	10

Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN)																			TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		200	190	180	170	160	150	140	130	120	110	100	90 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
210	10												1						6		7	1
Max O_2 = 17.7%	20												4						10	28	42	2
Min O_2 = 16.0%	30												5	3	1	3	2	8	15	60	97	3
	40												8	2	2	10	11	9	14	94	150	4
	60												14	12	11	10	10	9	58	102	226	6
	80							3	4	3	1		18	12	11	10	9	9	103	107	290	8
	100							4	6	2	3	3	18	12	11	9	19		139	114	340	9
	120							4	5	6		7	18	11	11	20	8		164	129	383	10
220	10												1						8		9	1
Max O_2 = 17.0%	20												3	2	2				9	33	49	2
Min O_2 = 16.0%	30												7	2	2	2	7	9	15	66	110	3
	40												9	2	8	11	11	9	14	101	165	4
	60						1	3	3	1			18	12	11	10	9	9	72	102	251	6
	80							6	3	4	4	6	18	12	11	10	9	9	118	109	319	8
	100							9	4	6	4	7	19	11	10	10	18		150	124	372	10
	120							5	4	4	10	12	18	12	11	28			175	136	415	11
230	10												1						8		9	1
Max O_2 = 16.3%	20												4	3					13	37	57	2
Min O_2 = 16.0%	30												8	2	3	3	10	10	15	72	123	3
	40												10	6	12	11	9	9	21	103	181	5
	60						5	4	3	3	2		19	12	11	9	10	8	87	103	276	7
	80						5	3	5	3	7	12	18	12	11	10	18		131	113	348	9
	100						8	5	3	6	8	12	19	11	10	17	11		162	130	402	10
	120						5	3	4	9	14	12	17	12	13	27			186	145	447	12

Depth (fswg) FO₂ %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN) 200	190	180	170	160	150	140	130	120	110	100	90 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)	TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		BOTTOM MIX																				
240	10												1						12		13	1
Max O_2 = 15.7%	20												6	3	3	1	2		17	47	79	3
Min O_2 = 12.0%	30												11	2	2	11	11	10	14	93	154	4
	40												16	13	12	10	10	8	37	110	216	5
	60				10	4	2	11	1	3	2	7	21	12	10	10	18		125	114	350	8
	80				8	8	4	4	2	4	20	17	20	11	10	29			167	131	435	10
	100				7	3	4	4	14	10	20	16	19	11	29	27			186	148	498	12
	120				15	6	1	1	4	18	20	16	19	26	58	28			186	148	546	12
250	10													2					13		15	1
Max O_2 = 15.2%	20												7	2	3	2	3	4	17	51	89	3
Min O_2 = 12.0%	30												12	3	8	11	10	10	14	101	169	4
	40					6	1						22	13	11	10	9	9	53	109	243	6
	60			8	2	7	7	9	12	2	2	3	20	12	11	10	18		143	119	385	9
	80			10	5	3		7	3	17	20	16	19	12	11	29			179	140	471	11
	100			11	4	3		8	16	14	18	17	19	12	55	23			188	146	534	12
	120			11	4	4	17		10	12	19	17	19	49	59	28			186	147	582	12
260	10												1	1	2				9	4	17	1
Max O_2 = 14.6%	20												8	2	3	2	3	8	17	57	100	3
Min O_2 = 12.0%	30												13	5	12	11	10	9	15	109	184	5
	40				3	7	4	4	2				21	12	11	10	10	9	77	102	272	6
	60		5	8	2	5	1	6	6	5	19	14	20	11	11	10	18		151	126	418	10
	80		7	11	14	3		3		17	20	16	19	12	27	23			188	148	508	12
	100		12	1	13	3	14		5	18	19	17	19	29	59	26			187	148	570	12
	120		6	10	18		5	9	7	15	19	17	40	53	58	26			187	146	616	12

Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN)																			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)		
270	10												2						18	3	23	1
Max O_2 = 14.2%	20												9	4	1	2	7	9	17	62	111	3
Min O_2 = 12.0%	30												15	12	11	10	10	9	21	111	199	5
	40				8	4	4	5	5	5	1		21	12	11	10	9	9	92	105	301	7
	60		8	5	8	19	12		3	2	5	16	19	12	10	29			169	134	451	11
	80	11	10	2	5	5	12		12	10	19	17	19	12	49	24			188	147	542	12
	100	11		23	4	4	7		10	18	19	17	19	50	59	28			186	148	603	12
	120	12	3	8			21	7	16	19	19	16	52	53	59	29			186	147	647	12
280	10												2	2					23	2	29	1
Max O_2 = 13.7%	20												10	3	1	3	10	10	15	71	123	3
Min O_2 = 12.0%	30												22	12	11	11	9	9	27	117	218	5
	40			7	9	4	2	5	2	5	5	4	22	12	10	10	9	9	106	110	331	8
	60	10	3	7		7	19	1	5	7	19	16	19	12	11	28			178	139	481	11
	80	12	3	25	6	6	3	16		5	19	17	18	28	58	27			186	148	577	12
	100	15	10	24	3		6		15	14	19	17	41	53	60	27			186	146	636	12
	120	13	9	12	8	8	1	10	16	18	19	17	70	53	59	34			183	149	679	12
290	10												2	2	2				9	18	33	1
Max O_2 = 13.3%	20												12	2	2	7	10	10	15	77	135	4
Min O_2 = 12.0%	30					10	2						22	12	11	11	10	8	53	107	246	6
	40		4	13	14			6	1	4	9		21	12	11	10	12	6	123	114	360	8
	60	10	10	19	8	3	9	4	3		18	16	19	12	24	26			187	148	516	12
	80	20	20	1	2	4	11	8	7	20	15	17	19	47	58	29			186	145	609	12
	100	25	27	8	2	4		3	10	17	19	17	60	53	60	32			183	147	667	12
	120	19	18	9	12	11	8		8	19	33		97	54	60	36			181	148	713	11

Depth (fswg) FO_2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN) BOTTOM MIX																			TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
		200	190	180	170	160	150	140	130	120	110	100	90 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
300	10												3	2	2				8	23	38	2
Max O_2 = 12.9%	20												13	2	2	12	10	9	15	84	147	4
Min O_2 = 12.0%	30				7	6	4	4	2				21	13	10	10	10	9	70	104	270	6
	40		11	10	2	2	15	9			3	12	20	12	11	11	17		138	117	390	9
	60	14	8	22	7	8	5	13	12	3		17	19	12	51	25			187	146	549	12
	80	24	23	1	11	15	7	9		6	19	17	36	53	58	26			187	147	639	12
	100	43	17	3			3	9	16	18	18	18	72	53	59	36			183	149	697	12
	120	29	5	14	11		9	16	17	17	35		102	54	59	40			179	152	739	12
310	10												4	2	2				8	28	44	2
Max O_2 = 12.5%	20												14	2	7	11	11	9	14	91	159	4
Min O_2 = 12.0%	30				13	4	4	4	4	2			22	12	11	10	10	8	84	106	294	7
	40	8	7	1	8	10	14	1	1	3	8	16	20	12	10	10	18		148	122	417	10
	60	16	26	6	12	3	13		5	5	19	17	18	19	59	27			186	147	578	12
	80	31	9	12	27				13	18	19	18	44	53	61	34			185	143	667	11
	100	17	19	15	3	18	9	10	17	18	19	18	78	54	59	38			180	152	724	12
	120	40		6	10	19	5	15	17	18	36		114	55	60	51			172	160	778	12
320	10												4	4					10	32	50	2
Max O_2 = 12.2%	20												15	2	12	11	10	9	15	97	171	4
Min O_2 = 12.0%	30			9	7	4	4	5	3	4	4	3	21	12	10	10	10	9	98	107	320	7
	40	11	4	4	5	9	30		1		6	16	20	11	11	17	11		159	130	445	10
	60	32	18	1		17	11	9		11	17	17	18	37	59	34			182	146	609	11
	80	23	42	9	1	8		9	17	12	18	18	65	54	62	35			183	142	698	11
	100	66	3	4	11	1		11	17	18	35	1	108	55	62	68			164	162	786	11
	120	51	1	6	7	12	14	15	18	50			146	57	64	72	81		117	173	884	10

Depth (fswg) FO2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN) 200 BOTTOM MIX	190	180	170	160	150	140	130	120	110	100	90 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)	TOTAL IWD STOP TIME (min)	Chamber O_2 Periods
330	10												5	2	3				11	34	55	2
Max O_2 = 11.8%	20												16	7	12	11	10	9	14	105	184	4
	30		4	11	4	6	7	4	2	5	8		22	12	10	10	10	8	110	112	345	8
	40	19	12	2	16	4	7	3	2	8	4	16	19	12	10	29			172	137	472	11
	60	35	23	10	12	4			4	20	17	17	19	52	61	35			183	145	637	11
	80	49	35		7	8			13	16	20	17	86	55	63	59			169	156	753	11
340	10												6	4					17	34	61	2
Max O_2 = 11.5%	20												17	13	11	11	9	9	14	112	196	5
	30		11	10	7	4	1	2	5	5	4	13	21	12	10	10	19		124	113	371	8
	40	24	4	3	3	11	10	4	16	5	11	16	19	12	11	28			178	144	499	11
	60	39	27	11	10		7	8		13	19	18	35	53	60	37			181	148	666	11
	80	59	31		1	6		12	14	17	161	120	92	59	65	77	88	93	65	174	1134	8
350	10												7	2	2	3			17	38	69	2
Max O_2 = 11.2%	20					3							24	12	11	12	9	8	25	118	222	5
	30	7	13	12	10	7	6	7			6	5	21	12	10	11	17		148	125	417	10
	40	22	18	21	7	8		3		7	21	18	19	12	41	35			182	148	562	12
	60	48	54	4	1	1		5	7	17	21	20	71	54	60	56			170	159	748	11
360	10												7	3	2	2	4		17	42	77	2
Max O_2 = 10.9%	20					13							23	12	11	10	10	9	45	113	246	6
	30	14	11	4	2	8	12	12	1	2	6	16	20	12	11	10	18		154	130	443	10
	40	33	8	31	3	1	6	8		8	18	19	18	13	59	36			181	149	591	12
	60	76	29	2	1	7		6	11	15	40	1	105	58	65	74	84	38	97	168	877	9

Depth (fswg) FO$_2$ %	Bottom Time (min)	DECOMPRESSION STOPS (FSW) STOP TIMES (MIN)																			TOTAL IWD STOP TIME (min)	Chamber O$_2$ Periods
		200	190	180	170	160	150	140	130	120	110	100	90 (50)	80 (50)	70 (50)	60 (50)	50 (50)	40 (50)	30 (100)	20 (100)		
		BOTTOM MIX																				
370	10												8	2	3	2	3	4	16	46	84	3
Max O$_2$ = 10.6%	20				5	16					2		22	12	11	10	9	9	60	112	268	6
	30	21	3	14	7	6	9	15	3		9	7	21	11	10	29			169	137	471	11
	40	46	17	8	1		2	3	11	21	22	17	18	23	59	39			179	153	619	12
380	10												10	2	2	2	3	8	16	51	94	3
Max O$_2$ = 10.4%	20				15	9	5	4	2				22	13	10	10	10	9	84	111	304	7
	30	30	2	6	12	10		5		18	22	19	20	11	11	34			181	149	530	12
	40	56	38	3	1	9			10	14	17	21	36	53	60	44			176	154	692	12

Appendix E. Revised LEM-HeN2_2016 Candidate Replacement Surface-Supplied Helium-Oxygen Decompression Table

Schedules in Table E-1 were computed with the LEM-HeN2_2016 model to incur an estimated risk of DCS no higher than 2.3% assuming divers breathe the minimum bottom gas O_2 fraction given for each dive depth group in Table 3 after accommodation of the ±0.5% gas mixing error allowed in the *U.S. Navy Diving Manual*.

A 75 fpm descent rate and 30 fpm ascent rate was assumed.

Times at all decompression stops except the first and those including a breathing gas switch include travel time to the stop.

Tabulated in-water stop times at 30 and 20 fsw do not include a recommended 5-minute air-breathing break after each 30 minutes of O_2 breathing. Times at these stops were computed assuming a conservative diver inspired O_2 fraction of 90%, while delivery of 100% O_2 is recommended during these periods in normal operations.

A double line in a dive depth group separates normal exposure dives above the line from exceptional exposure dives below the line as given for the group in the current U.S. Navy Surface-Supplied Helium-Oxygen Decompression Table.

Table E-1. Revised LEM-HeN2_2016 Candidate Replacement Surface-Supplied Helium-Oxygen Decompression Table

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)		
60	10																				0	
Max O_2 = 40.0%	20																				0	
Min O_2 = 21.0%	30																				0	
	40																				0	
	60																		2		2	1
	80																			18	18	1
	100																			38	38	2
	120																			56	56	2
70	10																				0	
Max O_2 = 40.0%	20																				0	
Min O_2 = 21.0%	30																				0	
	40																				0	
	60																		8		8	1
	80																			34	34	2
	100																			56	56	2
	120																			76	76	3
80	10																				0	
Max O_2 = 38.0%	20																				0	
Min O_2 = 21.0%	30																				0	
	40																		3		3	1
	60																		1	21	22	1
	80																		2	48	50	2
	100																		2	72	74	3
	120																		2	92	94	4

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	32	35	2
	80												1						2	62	65	3
	100												1						2	87	90	3
	120												1						13	98	112	4
100	10																				0	
Max O$_2$ = 32.3%	20																				0	
Min O$_2$ = 21.0%	30												1						3		4	1
	40												1						7		8	1
	60												1						3	43	47	2
	80												1						4	74	79	3
	100												1						8	97	106	4
	120												1						30	98	129	5
110	10																				0	
Max O$_2$ = 30.0%	20																		4		4	1
Min O$_2$ = 21.0%	30												1						4		5	1
	40												1						4	13	18	1
	60												1						5	54	60	2
	80												1						5	87	93	4
	100												1						22	99	122	5
	120												1						46	99	146	5

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)		
120	10																				0	
Max O_2 = 28.0%	20												1						3		4	1
Min O_2 = 21.0%	30												1						6		7	1
	40												1						5	22	28	1
	60												1						6	65	72	3
	80												1						7	99	107	4
	100															2			36	100	138	5
	120															2			61	100	163	6
130	10																				0	
Max O_2 = 26.3%	20												1						4		5	1
Min O_2 = 21.0%	30												1						9		10	1
	40												1						6	31	38	2
	60														2				7	76	85	3
	80														2				19	101	122	5
	100														3				49	100	152	5
	120														2	2			74	101	179	6
140	10																				0	
Max O_2 = 24.8%	20												1						4		5	1
Min O_2 = 21.0%	30												1						17		18	1
	40												1						8	40	49	2
	60													1	3				11	82	97	4
	80													1	2	2	3		30	98	136	5
	100													1	2	2	3	3	60	98	169	6
	120													1	2	2	2	6	85	100	198	7

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)		
150	10																				0	
Max O_2 = 23.4%	20												1						5		6	1
Min O_2 = 21.0%	30												1						7	19	27	1
	40													2					8	49	59	2
	60												1	1	2	6			15	86	111	4
	80													2	2	2	3	8	38	99	154	5
	100													2	2	3	4	10	68	98	187	6
	120													2	2	3	6	9	93	102	217	7
160	10																				0	
Max O_2 = 22.2%	20												1						7		8	1
Min O_2 = 21.0%	30												2						8	26	36	2
	40												1	1	3				9	55	69	3
	60												1	2	2	2	3	9	15	93	127	4
	80												1	2	3	2	10	9	46	98	171	5
	100												1	3	3	4	10	10	76	99	206	6
	120												1	2	3	7	11	9	101	103	237	7
170	10												1						4		5	1
Max O_2 = 21.2%	20												1						11		12	1
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
	80												5	2	2	11	10	10	66	99	205	6
	100												5	2	6	11	10	10	96	103	243	7
	120												5	2	8	11	15	5	122	110	278	8

Depth (fswg) FO2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW)																			TOTAL IWD STOP TIME (min)	Chamber O2 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)		
180	10												1						4		5	1
Max O_2 = 20.1%	20												2						17	1	20	1
Min O_2 = 16.0%	30												2	3	2				7	51	65	2
	40												4	3	1	3	2	6	15	72	106	3
	60												5	3	2	9	11	9	36	100	175	5
	80												6	2	11	11	10	9	73	101	223	6
	100												6	7	11	11	10	9	104	105	263	7
	120												6	9	11	11	19		129	114	299	9
190	10												1						4		5	1
Max O_2 = 19.2%	20												2						8	17	27	1
Min O_2 = 16.0%	30												4	4					15	51	74	3
	40												5	2	2	3	5	9	15	80	121	4
	60												7	2	9	11	10	9	44	100	192	5
	80												7	11	12	10	10	9	81	103	243	7
	100												11	13	11	10	10	8	112	109	284	8
	120												14	13	10	10	19		137	118	321	9
200	10												1						4		5	1
Max O_2 = 18.4%	20												1	3					8	26	38	2
Min O_2 = 16.0%	30												4	2	2	3	3	3	15	57	89	3
	40												7	2	3	3	12	9	15	88	139	4
	60												8	9	12	10	10	9	52	102	212	6
	80								1				17	12	11	10	9	9	91	105	265	7
	100								3	5			17	12	11	9	19		126	111	313	8
	120								4	3	4		17	12	10	11	18		151	124	354	10

Depth (fswg) FO2 %	Bottom Time (min)	DECOMPRESSION STOPS (FSW)																			TOTAL IWD STOP TIME (min)	Chamber O2 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)		
210	10												1						6		7	1
Max O_2 = 17.7%	20												2	3					8	32	45	2
Min O_2 = 16.0%	30												6	2	2	2	3	9	15	63	102	3
	40												8	2	2	11	11	9	15	96	154	4
	60												15	13	11	10	9	9	60	103	230	6
	80							3	3	4	3		18	13	10	9	10	9	107	106	295	8
	100							4	6	2	3	5	18	12	10	10	18		139	117	344	9
	120							4	6	1	4	9	17	12	10	29			166	129	387	10
220	10												1						6		7	1
Max O_2 = 17.0%	20												4	3					8	37	52	2
Min O_2 = 16.0%	30												7	2	2	3	7	10	16	68	115	3
	40												9	3	9	11	10	9	17	102	170	4
	60							5	3				18	12	11	10	9	9	75	103	255	6
	80						3	3	4	3	6	6	18	12	11	10	11	7	120	111	325	8
	100						5	5		4	6	13	18	12	10	10	18		152	124	377	10
	120						5	5		9	5	12	18	12	10	28			177	139	420	11
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
	60					8	4	4	5	3	4		21	12	10	11	10	7	109	111	319	8
	80					12	18	1	1		5	14	20	12	10	11	17		157	129	407	10
	100					14	1	2	5	10	18	17	18	12	12	28			185	145	467	12
	120					8	3	5	5	15	20	17	18	12	53	27			185	148	516	12

Depth (fswg) FO2 %	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)		
240	10												1						10		11	1
Max O_2 = 15.7%	20												6	2	5				16	48	77	3
Min O_2 = 12.0%	30												11	2	3	10	11	9	15	93	154	4
	40												15	14	11	10	10	9	37	109	215	5
	60				8	5	3	6	3	5	3	10	20	12	11	10	18		125	114	353	8
	80				15	11	5	3	2		13	16	20	12	11	27			170	137	442	11
	100				7	8	4	1	16	8	20	17	19	11	35	25			186	149	506	12
	120				12		3	5	16	13	20	18	18	30	59	25			186	148	553	12
250	10												1						11		12	1
Max O_2 = 15.2%	20												7	2	3	2	3	3	16	51	87	3
Min O_2 = 12.0%	30												13	2	7	11	10	10	15	100	168	4
	40					6							20	13	11	10	9	9	54	109	241	6
	60			8	10	4	8	11	1	1	9		20	12	11	11	17		143	123	389	9
	80			8	7		4	6	4	19	20	17	19	12	11	28			180	143	478	11
	100			11	7	8		6	7	18	20	18	18	13	58	26			186	147	543	12
	120			9	6	8	5		17	18	20	17	18	51	59	26			186	149	589	12
260	10												2						10	5	17	1
Max O_2 = 14.6%	20												8	2	3	3	2	7	17	56	98	3
Min O_2 = 12.0%	30												14	3	12	11	11	9	15	108	183	5
	40					10	4	5					20	12	11	10	10	9	76	105	272	7
	60		9	4	5	11	8	1		3	13	16	20	12	10	11	17		155	129	424	10
	80		11	1	10	3	1	2	14	20	19	18	18	12	27	25			186	149	516	12
	100		15	10	2	9		6	8	19	21	17	19	35	59	26			186	147	579	12
	120		21	4	4	12			15	17	20	17	42	53	59	30			184	147	625	12

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)		
270	10												2						14	3	19	1
Max O_2 = 14.2%	20												10	2	2	2	5	10	16	63	110	3
Min O_2 = 12.0%	30												15	10	12	11	9	9	21	111	198	5
	40				10	3	4	5	4	5			21	12	11	10	9	9	93	106	302	7
	60	7	3	11	3	10	10	5	2	9	5	17	19	12	12	27			171	135	458	11
	80	8	9	6	21	2		3	12	8	36		18	12	57	27			186	148	553	12
	100	10	5	3	17	8	1	10	10	19	35		26	52	59	26			187	145	613	12
	120	8	8	13	7	12	8	9	11	9	20	18	61	53	59	31			184	147	658	12
280	10												2	2					19	2	25	1
Max O_2 = 13.7%	20												11	2	2	2	9	10	15	70	121	3
Min O_2 = 12.0%	30					1							21	12	11	10	10	8	27	116	216	5
	40			7	11	3	3	3	4	3	10		21	12	12	9	17		111	108	334	8
	60	13	7	16		2	5		8	9	18	17	20	11	11	28			183	142	490	11
	80	8	10	16	9	8	1	11	26	25			18	41	59	25			187	145	589	12
	100	16	17	6	13	12	1		7	19	20	18	44	53	60	29			184	147	646	12
	120	15	10	24			10	12	8	18	21	18	78	53	59	35			182	148	691	12
290	10												3	3					23	2	31	1
Max O_2 = 13.3%	20												12	2	2	6	10	10	14	77	133	4
Min O_2 = 12.0%	30					11							20	14	10	10	11	7	51	109	243	6
	40		4	11	2	4	4	8	6		18		20	12	11	11	17		124	113	365	8
	60	18	7		4	6	2	18	4	14	36		19	12	25	25			186	148	524	12
	80	13	9	19	15	2			32	37			22	53	60	26			186	146	620	12
	100	12	16	20	2	3	6	12	17	20	19	19	54	54	59	32			183	149	677	12
	120	13	9	9	9	7	16	16	18	18	21	17	86	53	60	38			179	152	721	12

Depth (fswg) FO₂ %	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)		
300	10												3	2	2				8	21	36	1
Max O_2 = 12.9%	20												13	2	2	10	11	9	15	83	145	4
Min O_2 = 12.0%	30				5	10	4	2					21	12	11	10	10	8	69	107	269	6
	40		12	13	8	1	1	7	8		14		20	12	11	11	17		139	120	394	9
	60	15	14	22	4			9	11	7	18	18	18	13	52	23			187	146	557	12
	80	16	23	18	17		7	7		14	20	18	39	53	58	30			184	146	650	12
	100	29	12		7	4	16	16	17	20	20	18	68	53	59	35			181	151	706	12
	120	28	15	7	8	4	10	16	17	19	37		105	54	60	40			178	153	751	12
310	10												4	2	2				7	26	41	2
Max O_2 = 12.5%	20												14	2	6	11	11	9	14	90	157	4
Min O_2 = 12.0%	30			1	12	4	5	4	7				20	12	11	10	10	8	85	107	296	7
	40	8	11	17	5	3		4	5	6	15		20	12	10	11	17		153	126	423	10
	60	23	3	19	4	14	21			7	20	18	18	21	58	31			184	148	589	12
	80	34	17	2	15	8	8	57					70	54	59	35			181	147	687	11
	100	20	19	11	12	22	1	10	17	20	20	17	85	54	59	40			178	153	738	12
	120	19	12	12	14	16	14	16	18	19	37		116	54	61	53			171	159	791	12
320	10												5	2	3				8	33	51	2
Max O_2 = 12.2%	20												16	3	10	11	10	9	14	103	176	4
Min O_2 = 10.0%	30			10	15	6	3	5	5	3	5		22	12	11	9	19		117	116	358	8
	40	22	16		1	10	3	7	8	1	43		20	12	11	29			180	148	511	11
	60	47	9	25	1	7	9	8		22	23	22	45	53	59	38			178	149	695	11
	80	42	27	12	5	2	11	21	20	23	28	18	90	53	61	43			175	157	788	12
	100	47	17	10	8	15	19	19	21	28	41		134	56	63	70	52		133	167	900	11
	120	82				18	19	20	229	482	420		115	60	67	77	88	100	63	174	2014	8

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)		
330	10												6	4					9	38	57	2
Max O_2 = 11.8%	20												18	6	11	11	10	9	13	111	189	5
Min O_2 = 10.0%	30		3	17	14	4	5	2	3	5	12		23	11	11	9	18		129	125	391	9
	40	23	18	7	20				7	7	22	19	19	12	32	32			182	147	547	11
	60	59	26	11	4	2	2	1	15	18	44		63	54	61	42			179	149	730	11
	80	60	27	10	8		5	20	21	25	44		116	55	63	70	36		145	160	865	11
340	10												7	4					12	40	63	2
Max O_2 = 11.5%	20												19	11	11	10	10	9	14	118	202	5
Min O2 = 10.0%	30		14	17	15			9	5		6	11	22	11	10	10	18		146	128	422	10
	40	30	3	6	16	14	15	7			26	20	19	12	47	37			179	150	581	11
	60	54	25	1	14	8		22	23	49			85	55	60	44			176	149	765	11
350	10												8	2	3				15	41	69	2
Max O_2 = 11.2%	20					1							22	13	11	10	10	9	20	125	221	5
Min O_2 = 10.0%	30	7	16	7	4	5	12	10	2	5	6	18	22	11	11	10	17		155	135	453	10
	40	40	6	8	25				12	13	43		19	21	59	40			179	151	616	12
	60	64	40	10	1		4	16	11	19	45		94	56	63	72			162	160	817	11
360	10												8	3	2	4			16	44	77	3
Max O_2 = 10.9%	20					12							22	13	11	10	10	8	45	121	252	6
Min O_2 = 10.0%	30	17	15	17	17	1	6		3	17			21	11	11	28			174	146	484	11
	40	40	13	19	9		5	6	7	17	25	20	19	38	59	39			178	152	646	12

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)		
370	10												9	3	1	3	3	3	15	48	85	3
Max O_2 = 10.6%	20				3	20							22	12	11	10	10	8	66	118	280	7
Min O_2 = 10.0%	30	24	18	1	6	7	12		8	6	13	19	20	11	11	29			179	149	513	11
	40	49	34	8	2	4	1	1	13	11	44		23	54	60	45			176	154	679	12
380	10												10	2	2	3	2	7	17	50	93	3
Max O_2 = 10.4%	20				14	12	5	2					22	12	11	10	11	7	83	116	305	7
Min O_2 = 10.0%	30	29	7	15	7	14	6	3		11	12	20	20	11	24	40			178	152	549	12
	40	59	16		8	8	8	7	18	56			43	54	61	47			174	152	711	11