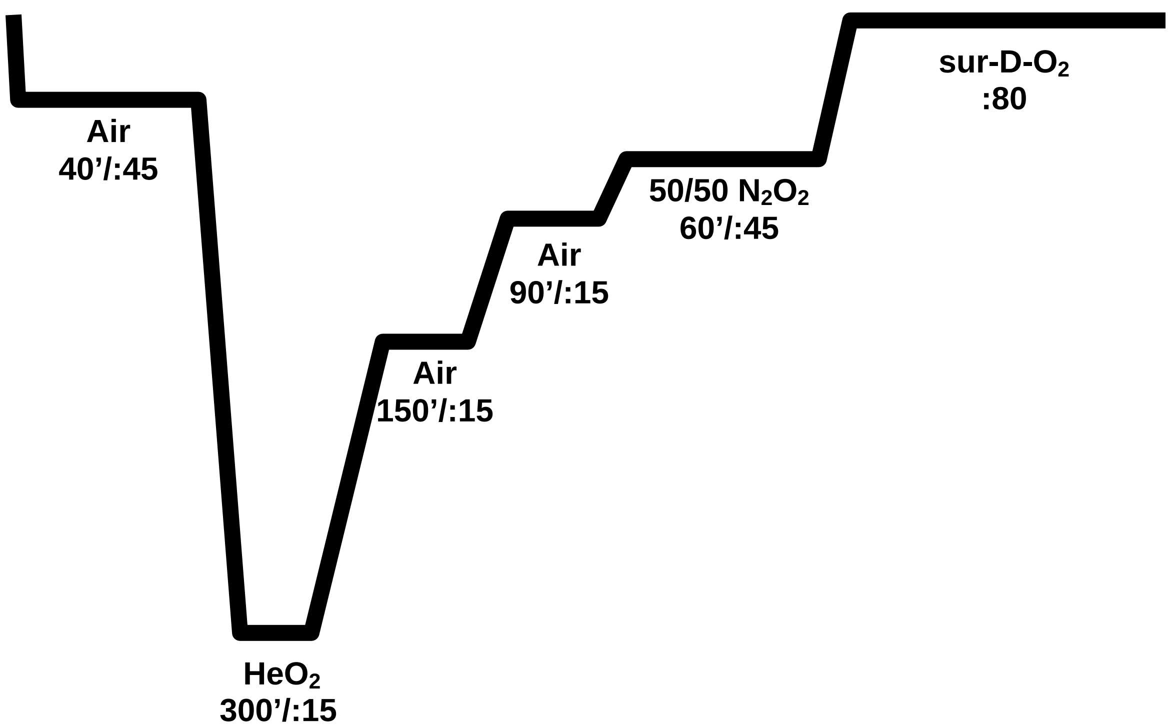
PROCEEDINGS OF ADVANCED SCIENTIFIC DIVING WORKSHOP



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EVALUATION OF DIVE COMPUTER OPTIONS FOR POTENTIAL USE IN 300 FSW HELIOX/TRIMIX SURFACE SUPPLIED SCIENTIFIC DIVING

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This evaluation examined dive computer options to support scientific surface-supplied diving on heliox or trimix to depths up to 300 fsw. Four dive computers were determined to be able to operate under these conditions: the Cochran Undersea Technology EMC-20H, the Delta P Technology VR3, the Dive Rite NiTek He, and the HydroSpace Engineering HS Explorer. Decompression software that simulates the dive computers responses to profiles was obtained and scenarios for dives to 300 fsw for 20 minutes were calculated using heliox and trimix with various gas mixtures. Since the focus of this workshop is on surface-supplied diving, it is recommended that the primary use of dive computers be to provide depth, time, and ascent rate information to the diver and record the profile, leaving the diver's decompression to be controlled by surface-support personnel. Because of the rapidly increasing TDT debt for the additional 5-10 minutes of bottom time it is recommended that bottom times at 300 fsw be limited to 20 minutes. In relation to the high decompression debt incurred on these dives very serious concern needs to be given to potential blow-up situations, which can produce fatal decompression sickness. Various established heliox decompression tables are available for use in this type of diving. However, if the dive computer or decompression software options are chosen then, in lieu of studies that have validated the decompression algorithm, divers must have enough comfort and experience with the decompression algorithms and protocols they intend to use, in order to justify their use to their Diving Control Boards.

Overview

The objective of this paper is to evaluate available dive computer options to support scientific surface-supplied diving on heliox or trimix to depths up to 300 fsw and provide recommendations for their use. This was done by examining the decompression features of the currently available dive computers to find which would allow heliox or trimix diving to 300 fsw or deeper. Four dive computers were found to fit the criteria. The decompression features of these dive computers were reviewed to determine the decompression algorithms they used and what level of gas switching capabilities they had. In order to determine the decompression requirements of these dive computers in dives to the proposed operating depth of 300 fsw, decompression software that simulated their response was obtained.

The decompression software that purportedly emulated the various dive computers was used to calculate the response to specific 300 fsw/20 min total bottom time (TBT) dive scenarios. These scenarios included:

- Heliox dive without decompression gas switches
- Heliox dive with one gas switch to nitrox during decompression
- Heliox dive with gas switches two different nitrox mixes during decompression
- Trimix dive with gas switches two different nitrox mixes during decompression
- Heliox dive following the US Navy protocols
- Heliox dive following the DCIEM (now DRDC) protocols

The US Navy and DCIEM table comparisons were included to see how the computer simulations compared to established heliox tables. These simulations were run with settings that represented the dive computers in their most liberal decompression algorithm settings, as well as with the addition of safety factors available in the dive computers.

The total decompression time (TDT) obligation from the most liberal dive computer for a heliox dive without decompression gas switches was unacceptably long (5 hours). It was determined that multi-gas decompression protocols are required for more efficient operations. Switching to a single nitrox decompression reduced the TDT dramatically. Adding an additional nitrox mix did not make a significant difference. Moving to a trimix bottom mix with two nitrox mixes for decompression did have a major impact on reducing the TDT. For the trimix scenario the required decompressions for the four simulations of the computers, in their most liberal mode, were within eight minutes of each other (89-97 minutes).

Comparison of the computer simulations to the US Navy heliox decompression tables (using the gas mixtures and depth switches prescribed by the US Navy) showed that in the most liberal mode the EMC-20H and VR3 exceeded the TDT required by the US Navy tables. In its most conservative setting the HS Explorer was able to exceed the US Navy TDT requirement if the air breaks were omitted.

In their most liberal settings the simulated computer requiring the most decompression for the comparison to the DCIEM heliox table (using the gas mixtures and depth switches prescribed by the DCIEM tables) was the Delta P VR3. However, it’s calculated total decompression time was still over 30 minutes shorter than the DCIEM tables. Only two of the simulated computers reached or exceed the DCIEM decompression requirements by adding in safety factors.

It is this author's opinion that in surface-supplied operations diver-carried dive computers are best used as a backup and that the major control of decompression should be assigned to the surface-support personnel using a preplanned set of tables that the dive computer emulates. In heliox operations there are established tables and protocols that are available, however, finding a computer that can be set to mirror their decompression requirements (both in total decompression time and decompression gas times) will prove difficult. In trimix operations software packages can be used to generate decompression tables that should closely reflect the dive computer's response. However, the paucity of data supporting the safety of models brings up risk management issues. In lieu of validation studies, organizations must have enough comfort with the decompression algorithms and protocols they use to be able to justify the use to their Diving Control Board. Concern also needs to be given to the potential of fatal decompression sickness in a blow-up situation.

Dive Computers

There are currently four dive computers on the market which will allow heliox and trimix diving to depths of 300 fsw:

- the EMC-20H – manufactured by Cochran Undersea Technology,
- the HS Explorer – manufactured by HydroSpace Engineering,
- the NiTek He – manufactured by Dive Rite, and
- the VR3 – manufactured by Delta P Technology

The manuals for these computers were obtained and reviewed for computer features and information regarding the decompression algorithms they utilize. There are many features of dive computers that can be compared. However, for this review the comparison is limited to decompression algorithms, number of gas mixtures, and any gas mixture limitations with regards to partial pressure of oxygen (PpO_2) or narcosis potential.

The following questions were e-mailed to the dive computer manufacturers regarding their dive computers and decompression algorithms:

- Have controlled human subject trials been performed to validate the decompression algorithm?
    - If yes, were any in the 300 fsw/20-30 min range?
    - If yes, have peer-reviewed papers been published on these trials and are reprints available?
- Do you collect documentation from uncontrolled (in the field) dives using this algorithm?
    - If yes, how many dives have been documented?
    - If yes, how much experience is there in the 300 fsw/20-30 min range?
    - If yes, what is the incidence of DCS that has been reported on this algorithm (if any)?

- Do you have a fuller description of the algorithm beyond what you have published in the manual and on your web site?
- Is there anything that you feel should be added to the description of the algorithm beyond what you have published in the manuals and on your web site?
- Is there a software package that will simulate the response of your dive computer to profiles?

The EMC-20H

The EMC-20H dive computer (Fig. 1) utilizes a "20 Tissue Adaptive Modified Haldanean" decompression algorithm. The computer adapts its algorithm in response to water temperature, rapid ascents ("microbubble"), and reverse profiles. The temperature adjustments are made in water cooler than 75° F and can be set to either "Normal" or "Reduced." In the "Reduced" mode the adjustment to the algorithm is about 150% of what it would be in "Normal" mode. There is no indication in the manual that the level of "microbubble" adjustment can be modified, but the reverse profile adjustment has the ability to be turned off. Additional conservatism from 0 – 50% can be set for the decompression algorithm. No information was available on the actual decompression algorithm or how the various adjustments modify the algorithm.

The user can enter up to three nitrox, heliox, or trimix gas mixtures. Limitations for the gas mixtures are 5.0 % to 99.9% oxygen in 0.1% increments and 0.0% to 95.0% helium in 0.1% increments. Gas switching in the calculations is determined by a preset minimum dive time and switch depths for both decompression mixes.

In their reply to the e-mail, Cochran reported that the Analyst 4.01P software would emulate the EMC-20H and sent a copy of it to be used in preparing this evaluation. They indicated that they were going to review the questions and follow-up with their answers, but at the time this paper is being written no further reply has been received.

The HS Explorer

The HS Explorer dive computer (Fig. 2) utilizes one of ten decompression algorithms. Seven of the algorithms are based on the Bühlmann ZH-L16C decompression model with differing degrees of offgassing asymmetry (100%, 118% and 135% of compartment ongassing half-time) and compartment gas loading allowances (100%, 97%, and 94% of ZH-L16C allowance). The other three algorithms are a "derivation of the Reduced Gas Bubble Model (RGBM)" with various levels of conservatism (100%, 97%, and 94% of model). The manufacturer had no validation information for the RGBM decompression algorithms and referred to Wienke's publications, which list various anecdotal reports supporting the efficacy of the model.

The user can enter up to ten nitrox, heliox, or trimix gas mixtures. Limitations for the gas mixtures are 5 % to 99% oxygen in 1% increments, 0 to 95% helium in 1% increments, and 0 to 79% nitrogen in 1% increments. Gas switching in the calculations is determined by a preset a descending or ascending gas switch depth for the different gas mixtures. At depth the diver manually confirms the gas switch.

Figure 1. Cochran Undersea Technology EMC-20H

Figure 2. HydroSpace Engineering HS Explorer

In their reply to the e-mail, HydroSpace Engineering answered that:

1. Dr. Wienke would be the person to contact regarding RGBM validation information
2. HydroSpace Engineering does not collect documentation from uncontrolled (in the field) dives using this algorithm. However, they did report that Dr. Wienke and Tim O'Leary have a number of dives in the 300 fsw depth range [1,136 in 200-300 fsw range] and that NAUI Tec is using RGBM exclusively. They reported that out of the people they know who have used the HS Explorer, nobody has reported any incidence of DCS.
3. Books by Dr. Wienke on RGBM were suggested for further information on the decompression model
4. HydroSpace Engineering did not answer question no. 4
5. They reported that the HS Explorer Simulator would simulate the ZH-L16C based algorithms and that GAP RGBM software would emulate the RGBM algorithms. The HS Explorer was obtained from their web site, but the cost of the GAP RGBM prevented its inclusion in this report.

The NiTek HE

Figure 3. Dive Rite NiTek HE

Figure 4. Delta P Technology VR3

The NiTek HE dive computer (Fig. 3) uses the Bühlmann ZH-L16C decompression model with no apparent way to modify the algorithm. No information was provided on the validity of the model.

The user can enter up to seven nitrox, heliox, or trimix gas mixtures. Limitations for the gas mixtures are 8 % to 99% oxygen in 1% increments, 0 to 92% helium in 1% increments. Gas switching in the calculations is done manually during the dive. A gas mix can not be locked into the dive computer if the PpO_2 is greater than 1.6 ata.

Dive Rite did not reply to the initial e-mailed questionnaire and a duplicate was sent with no response. However, based on information from various web sites it was concluded that Dive Rite's Dive Voyager Decompression Planning Software would emulate the NiTek He. A demo version of this software was obtained for the simulations in this report.

The VR3

The VR3 dive computer (Fig. 4) utilizes a decompression algorithm which is a "derivative of the Bühlmann ZHL 16 algorithm." It also contains "Deep-water microbubble controlling stops," which appear to be short one-minute stops taken halfway between the depth of the dive and the first model-based decompression stop, then halfway between the first deep stop and the first model-based decompression stop, continuing until the model-based stops are reached. The VR3 also allows a user-entered safety factor from 0 – 50%, which increases the inert gas content for calculations by 2% for every 10% increase in the safety factor. Only anecdotal information was provided to support the decompression algorithm's validity.

The VR3 has the ability to utilize ten gas mixes. One is permanently assigned to air and the user can enter up to nine nitrox, heliox, or trimix gas mixtures. If there were any limitations for the gas mixtures, no reference could be found in the VR3's literature. Gas switching in the calculations is determined by a preset descending or ascending gas switch depth for the different gas mixtures. At depth the diver manually confirms the gas switch.

In their reply to the e-mail Delta P Technology answered that:

1. No testing was done to validate the decompression algorithm.
2. VR3 does not collect data on uncontrolled dives, only emails saying things like "the whole team is fine after the project"
    a. None of the dives have been documented scientifically
    b. Delta P Technology reported that "the bulk of the diving is in the 60-70m range. However, we have a significant (300+) client base working in the 100m+ range"
    c. With regards to DCS incidence they stated, "General unpublished feedback is of no or little incidence of DCI. At this stage if we were getting significant [incidence] we would be definitely hearing about it and we are not"
3. Delta P Technology did not provide a fuller description of their algorithm because of concern about other people copying their product.
4. In terms of additional information about their decompression algorithm they stated, "The basic Bühlmann adaptation was put together in 1988. Since 2000, we put about 6000 units in the field, the majority working in the trimix mode".
5. They reported that Pro Planner software would simulate the response of the VR3. Delta P Technology provided a copy of Pro Planner to be used in preparation of this evaluation.

300 fsw Dive Scenarios

The dive scenarios selected to be simulated were based on various gas mixture combinations to the maximum depth of 300 fsw for 20 minutes. Initial simulations were made with the software emulating the dive computers algorithms' most liberal setting. The heliox simulations were based on running the gases PpO_2 close to 1.6 ata at their maximum depth of use. The trimix simulations were based on lower PpO_2 levels closer to what technical divers are using. Comparisons were also made with established US Navy and DCIEM heliox decompression tables using the same gas mixtures and gas switching depths indicated on the table. If any of the simulations did not meet or exceed the TDT requirements of the established table, then the software was adjusted until the TDT was met or the maximum level of conservatism was reached. Based on the adjustments that were made, the trimix dive was recalculated for 300 fsw/ 20, 25, and 30 min.

Heliox 15.9 – Single Gas

It was suggested that a single-gas heliox dive should be evaluated and that PpO_2 levels could reach 1.6 ata. Heliox 15.9 was selected to meet these criteria and a 300 fsw/20 min dive was simulated with the following conditions:

- Descent Rate 75 fsw/min.

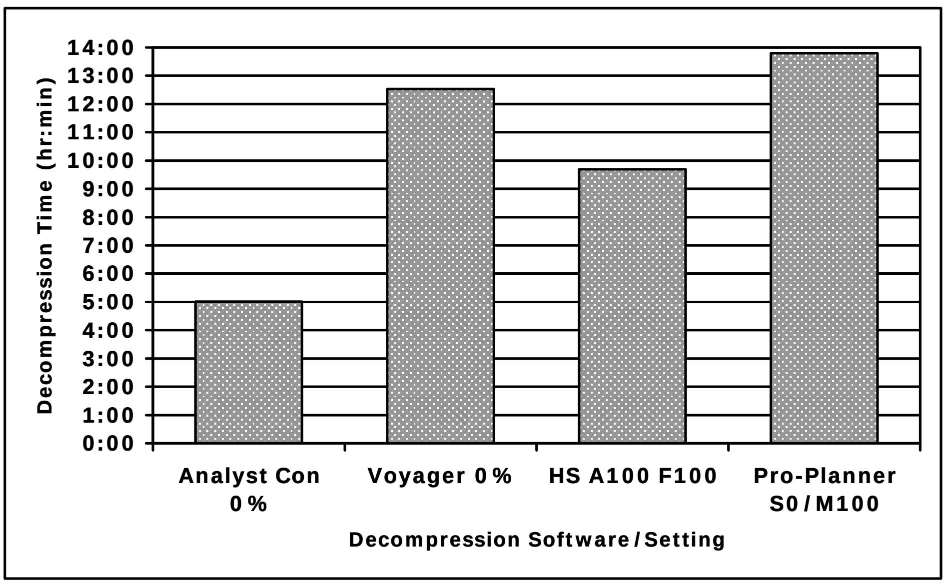

Figure 5. Decompression requirements for Heliox 15.9 300 fsw/20 min with no decompression gas switches.

- HeO_2 15.9 (0-300 fsw/300-0 fsw)
- Ascent Rate 30 fsw/min.

Decompression requirements resulting from this simulation ranged from 5 hours to almost 15 hours (Fig. 5). The long decompression requirements for a single heliox dive immediately eliminates it as a practical option.

Examining the depth of the first decompression stop for this scenario shows that the algorithms that state they control “microbubbles” produce deeper initial stops (Fig. 6).

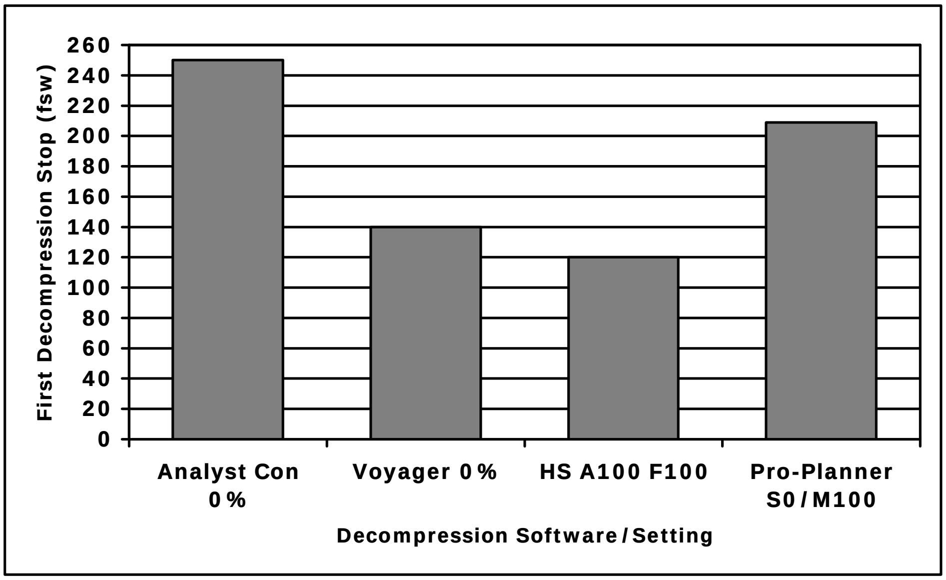

Figure 6. Depth of first decompression stop for Heliox 15.9 300 fsw/20 min dive.

Heliox 15.9 with EANx 50 decompression gas

In this scenario a decompression gas of 50/50 nitrox was added at decompression stops of 70 fsw and shallower. The PpO_2 of EANx 50 at 70 fsw is 1.56 ata. The addition of a single decompression mix greatly reduced the calculated TDTs to between 110 and 166 minutes (Fig. 7).

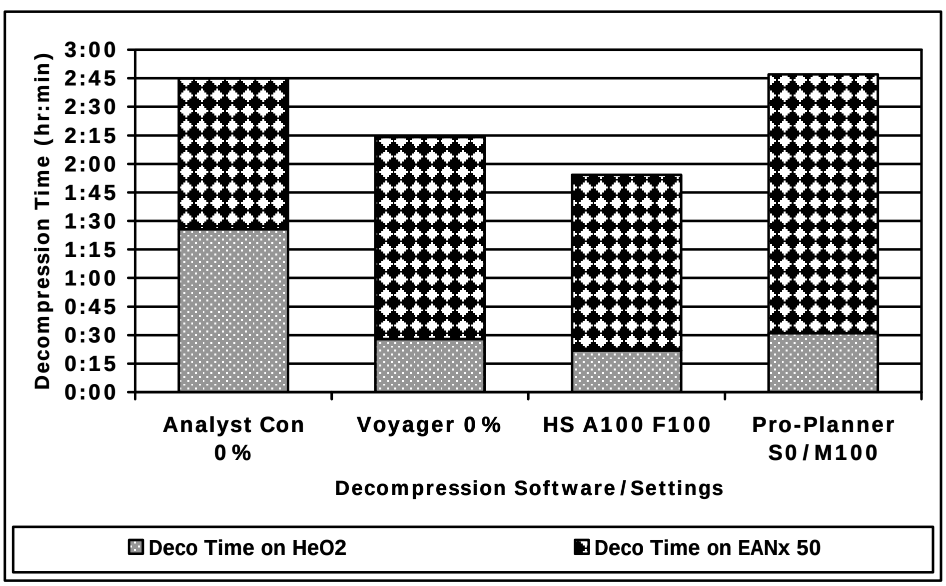

Figure 7. Decompression requirements for Heliox 15.9 300 fsw/20 min with EANx 50 at 70 fsw.

Heliox 15.9 with EANx 50 and EANx 80 as decompression gases

Adding nitrox 80/20 to the decompression at 30 fsw results in a PpO_2 of 1.53 ata, but does not significantly reduce the decompression requirements. The TDTs calculated with the addition of nitrox 80/20 were 99-154 minutes (Fig. 8).

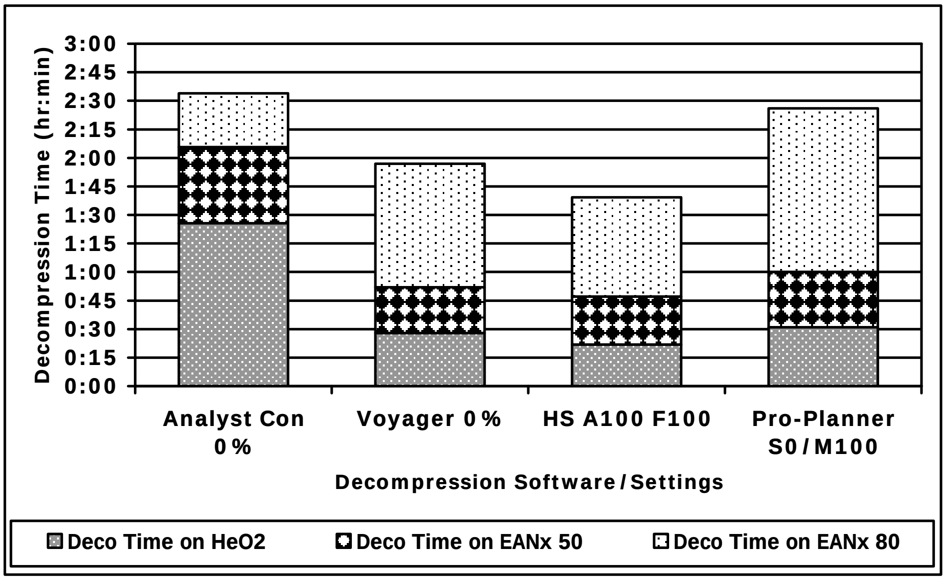

Figure 8. Decompression requirements for Heliox 15.9 300 fsw/20 min with EANx 50 at 70 fsw and EANx at 20 fsw.

Trimix 14/54 15.9 with EANx 50 and EANx 80 as decompression gases

A scenario was simulated based upon trimix with lower PpO_2s during the dive and at the end of the decompression. The bottom mix of trimix 14/54 gener

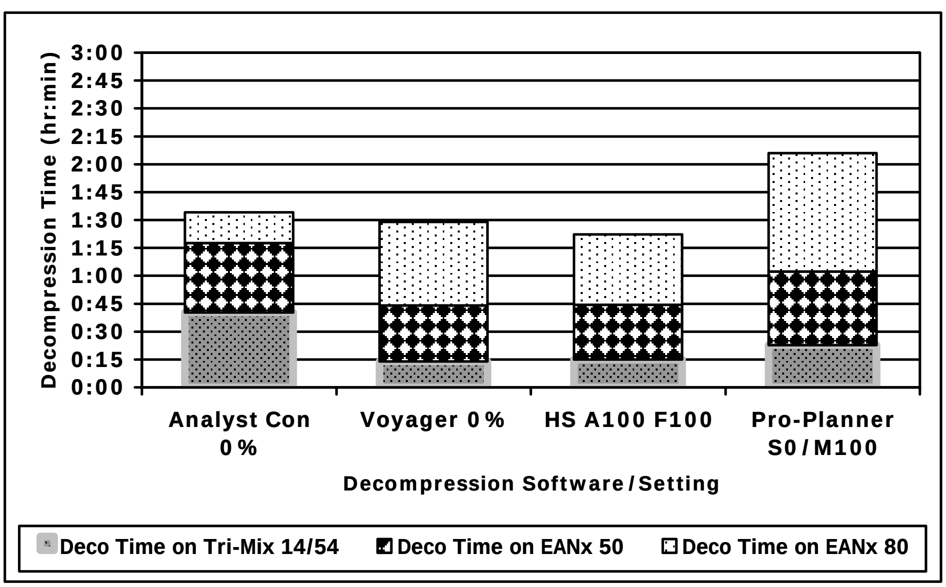

Figure 9. Decompression requirements for Trimix 14/54 300 fsw/20 min with EANx 50 at 70 fsw and EANx at 20 fsw.

ates a PpO_2 of 1.41 ata at 300 fsw and an equivalent narcotic depth of approximately 100 fsw. The nitrox 50/50 is used from 70 fsw to 20 fsw and the nitrox 80/20 is started at 20 fsw resulting in a PpO_2 of 1.28 ata. Even with the lower oxygen pressures the decompression requirements from all four programs dropped. The TDT range for this scenario was 82–126 minutes (Fig. 9).

Comparison to Established Heliox Decompression Tables

Since there is no hard evidence to suggest the level of safety associated with the decompression algorithms utilized in the dive computers and decompression software packages, a comparison was done with the established US Navy and DCIEM 300 fsw/20 min heliox decompression tables. The goal was to see if the decompression requirements of these tables were met, or exceeded, by the software simulations. If the requirements were not met then the algorithms that could be adjusted were set to either levels that met the table decompression requirement or to their maximum level of conservatism. Since, based on the available information, the NiTek HE algorithm is not adjustable; the Voyager software was not adjusted.

US Navy Heliox Tables

For the depth of 300 fsw the US Navy Heliox Tables use heliox 12.9/87.1, which results in a PpO_2 of 1.30 ata. To avoid hypoxia at the surface and on initial descent, air is breathed until a depth of 20 fsw. At 90 fsw decompression a switch is made to heliox 50/50, producing a PpO_2 of 1.86 ata. At 30 fsw oxygen is breathed (PpO_2 = 1.91 ata) and 5 minute air breaks are taken for every 30 minutes of oxygen breathing. The final decompression stop is at 20 fsw. The TDT for the US Navy 300 fsw/20 min heliox table is 160 minutes (including the air breaks).

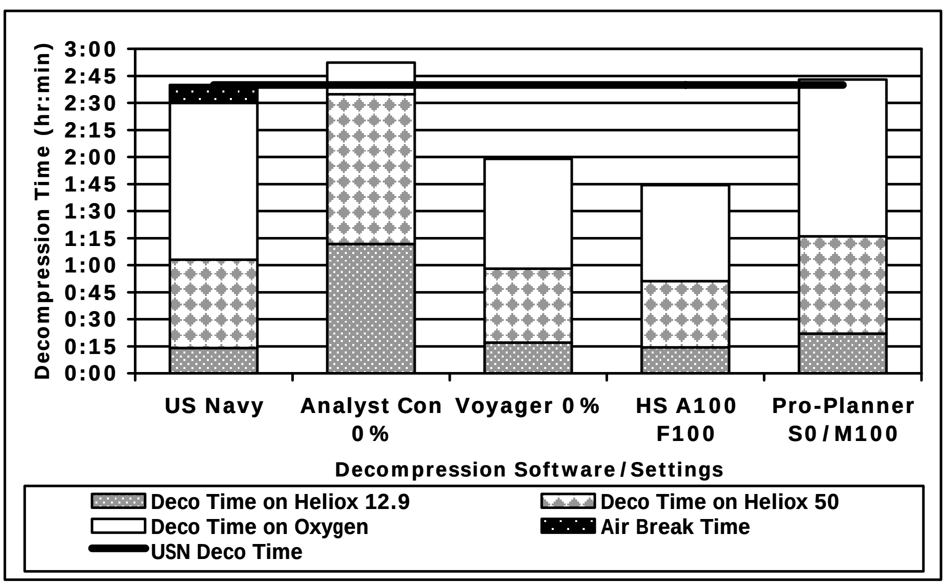

Figure 10. Decompression requirements for 300 fsw/20 min dive computer simulations vs. US Navy heliox tables.

The results from the simulations ranged from 104–172 minutes. The simul

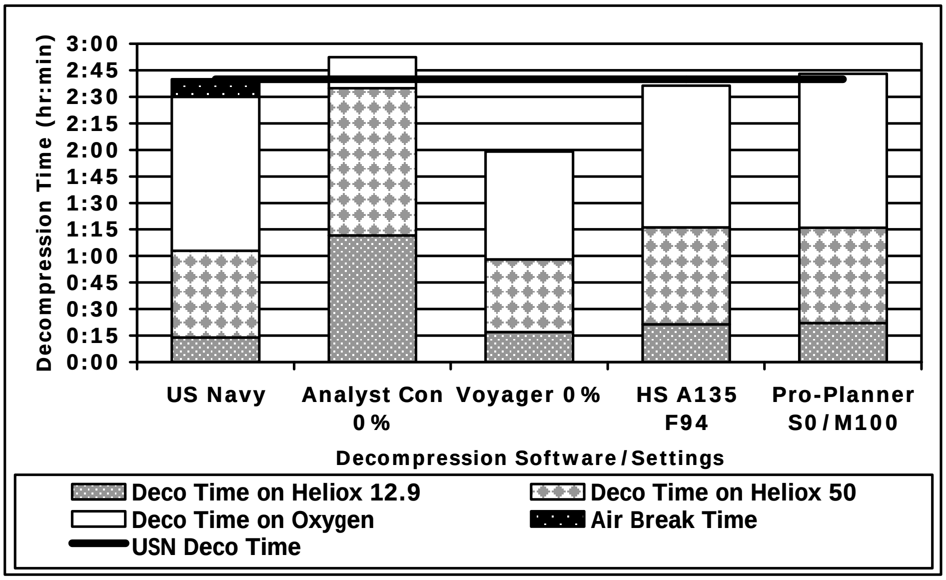

Figure 11. Decompression requirements for 300 fsw/20 min with adjusted dive computer simulations vs. US Navy heliox tables.

ations of the EMC-20H and VR3 computers met or exceeded the US Navy TDT. The NiTek and HS Explorer simulations showed at least 30 minutes less TDT (Fig. 10). When the HS Explorer was adjusted to its most conservative setting (A135 F94) it did not reach the US Navy TDT (Fig. 11), however if the same air break schedule were added it would reach the required TDT.

DCIEM Heliox Tables

The DCIEM Heliox Tables were validated with 1,471 manned exposures during their development. The tables state that the probability of decompression sickness is reduced to 2% in the normal range and 4% in the extreme exposure range. The 300 fsw/20 minute schedule is in the normal range (a bottom time of 30 minutes at 300 fsw enters the extreme exposure range). The DCIEM Heliox Tables use heliox 16/84 as the bottom mix (PpO_2 = 1.61 ata), switches to air at the first decompression stop (in the simulations air use was limited to 160 fsw), and a switch to oxygen at 30 fsw. Five minute air breaks are given for every 30 minutes of oxygen breathed and the last decompression stop is at 30 fsw.

None of the computer simulations reached or exceeded the DCIEM TDT requirement of 130 minutes. The range of the computer simulations was 64–109 minutes (Fig. 12). Adjusting the Analyst software to 25% conservatism and the Pro Planner safety factor to 15% produced TDTs equivalent to the DCIEM requirement while the HS Explorer at its most conservative setting (A135 F94) falls just 5 minutes short of the goal (Fig. 13). Once again, if the air breaks are added to the calculated decompression schedule, the HS Explorer would reach the table's TDT.

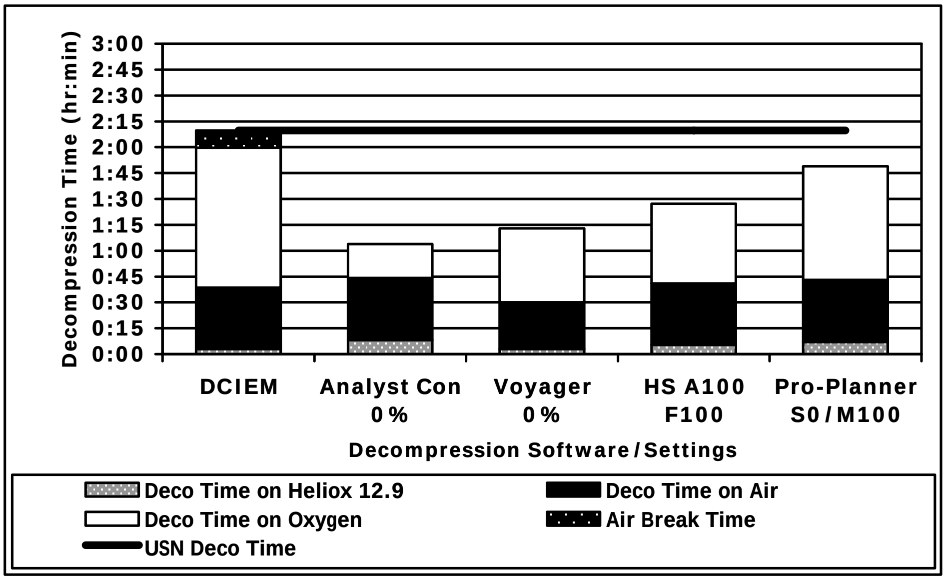

Figure 12. Decompression requirements for 300 fsw/20 min dive computer simulations vs. DCIEM heliox tables.

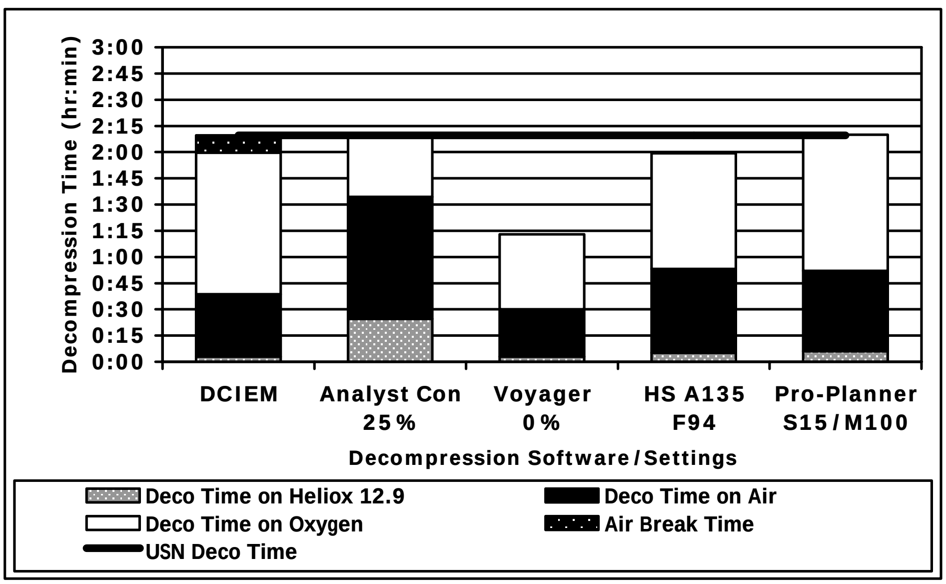

Figure 13. Decompression requirements for 300 fsw/20 min adjusted dive computer simulations vs. DCIEM heliox tables.

Table Comparison Issues

There were a few issues encountered in the simulations comparing the tables to the computer simulations:

- Only the Analyst and Voyager software packages allowed gases to be entered in fractions of a percent, so heliox 12.9 had to be entered as heliox 13 in Pro Planner and HS Explorer
- Pro Planner would not allow an entry of a gas which would exceed a PpO_2 of 1.60 ata. Therefore a depth of 297 fsw was used when the bottom mix was heliox 16

and the oxygen faction was adjusted to be as close to 1.6 ata as possible on decompression stops where the prescribed gas would have exceeded 1.6 ata.
- In the DCIEM simulation air is switched to at the first decompression stop. However, since some of the calculated stops were deeper than 200 fsw it was decided to set the air switch to 160 fsw, the deepest stop on the printed tables

Recalculating the Trimix Scenario

Based upon the comparisons of the computer simulations to established heliox tables, and the adjustments that needed to be made to achieve equivalent TDTs from software, the trimix dive scenario was recalculated using the levels of conservatism needed to meet the DCIEM table requirements. The Analyst software was set to 25% conservatism, the HS Explorer to A135 F94, and Pro Planner to a safety factor of 15%. Voyager was not adjusted. The resulting TDTs from the trimix simulation ranged from 110–146 minutes (Fig. 14). The increase in TDT was 52 minutes for Analyst, 35 minutes for HS Explorer, and 19 minutes for Pro Planner.

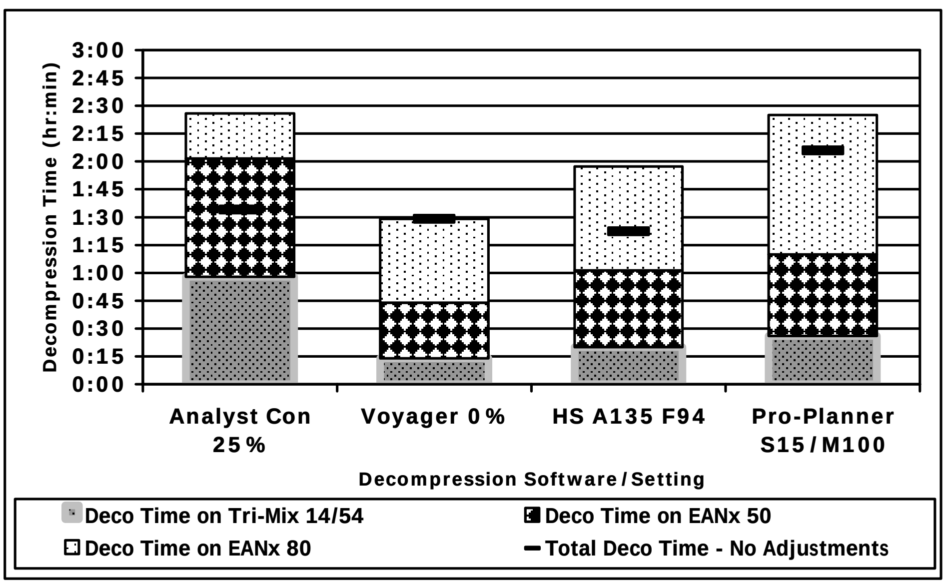

Figure 14. Decompression requirements for Trimix 14/54 300 fsw/20 min with adjusted dive computer simulations.

Simulations were also run with bottom times of 25 minutes and 30 minutes at these settings. The resulting TDT range for the 25 minute bottom time was 135–216 minutes and 178–291 minutes for the 30 minute bottom time. The addition of another five minutes to the bottom time resulted in 46 to 70 minutes of additional decompression time. For an additional ten minutes of bottom time 89 to 145 minutes of additional decompression time was required (Fig. 15).

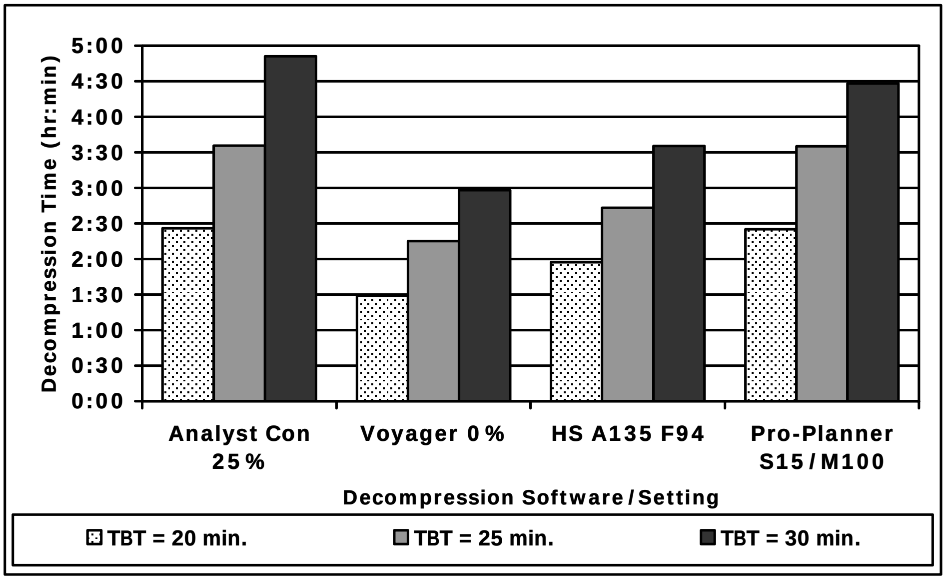

Figure 15. Decompression requirements for Trimix 14/54 300 fsw/20, 25, & 30 min with adjusted dive computer simulations.

Comments

As can be seen in these simulations, there are a plethora of possible decompression schedules available for a single 300 fsw/20 minute dive depending upon the decompression table or algorithm, any conservatism added to the algorithm, the composition of the bottom mix, and the decompression gases (composition and switch depth). The actual decompression schedule stops may vary greatly even though the same TDT is achieved. For example, the Analyst software tends to calculate most of the stops deeper and has shorter times with final decompression gas.

The main question is of the safety of the decompression scheduled generated by these computers, since there is little to no data available regarding their validity. Comparing them to established tables allows us to see if their schedules reach or exceed the table TDT requirement. Three of the four computers allow for adjustment to reach this mark. An obvious question that is raised in these comparisons is, “Why not use the established heliox tables and use computers as a back-up?”

A major concern in diving to these depths is the risk of fatal decompression sickness in the case of blow-ups from depth. Very serious consideration needs to be given to the Emergency Action Plan in case of a blow-up from depths as great as 300 fsw.

Recommendations

Based on the 300 fsw/20 min dives analyzed, the following recommendations are made for the currently available heliox/trimix dive computers:

- EMC-20H should be set to at least 25% conservatism.
- HS Explorer should be set to CF 9 (Asymmetric 135 / F=94).
- NiTek He not recommended (has no apparent algorithm adjustment).
- VR3 should be set to at least a Safety Factor of 15%.

- Dive computers may not be needed to control decompression for surface-supplied diving. Control of decompression can be handled by the surface-support personnel using established or “cut” tables.
- Dive computers still can be used to provide the diver with information on depth, time, and ascent rate, and be used as a backup to decompression tables.
- If dive computers are used, they can not be exposed to any gas filled environment in a decompression stage, way station, or decompression chamber.
- Bottom times for 300 fsw dives should be limited to 20 minutes.
- For heliox dives:
  - Surface support personnel with established tables control the diver’s decompression.
  - If a dive computer is used as a backup it should be able to be adjusted to require as much decompression time as the established tables – however, it will be difficult to find dive computers that can be adjusted to closely match the scheduled stops of US Navy or DCIEM decompression tables, even though the TDTs are the same.
- For trimix dives:
  - Decompression tables should be “cut” with a software program that will emulate the dive computer worn by the diver.
  - Surface-support personnel with these tables control decompression.
  - If a dive computer is used as a backup it should be adjusted to same level of conservatism as the “cut” tables.
  - Divers and scientific diving programs need to recognize that these trimix dive computers and software programs have not been validated with controlled studies.
  - Emergency protocols need to be established to be able to handle the possibility of diver blow-ups from depths that can potentially produce fatal decompression sickness

Conclusion

Scientific divers wishing to utilize surface-supplied heliox or trimix for diving to depths of 300 fsw need to be make decisions to either:

- Utilize established heliox decompression tables with the possibility of using dive computers as a backup.
- Cut heliox or trimix decompression tables using available decompression software packages with the possibility of using dive computers as a backup, or
- Use dive computers with heliox and trimix capabilities to control decompression.

If established tables are used then it will be difficult to closely match a dive computer to the decompression schedule of the tables.

If the dive computer or decompression software options are chosen then, in lieu of studies which have validated the decompression algorithm, the divers must have enough comfort and experience with the decompression algorithms and protocols they intend to use to be able to justify their use to their Diving Control Board.

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Addendum

At the workshop Karl Shreeves noted that he used the Dive Rite NiTek HE and that the decompression times calculated by the Voyager software seemed to be shorter than what he would expect for the NiTek HE. From his experience he has had better matching of decompression schedules with Abyss 120. He also noted that you could force the NiTek HE into more conservative calculations by setting it to a higher altitude range. However, when looking at the NiTek HE manual it does not say anything about manual altitude adjustment, instead it says the unit automatically adjusts to altitude changes.

The dive scenarios were recalculated using Abyss 120 to simulate the response of the NiTek HE dive computer and the results compared to Voyager calculations are presented in the table below:

Comparison of Voyager and Abyss 120 Decompression Requirements				
		Decompression Time (hr:min)		
Scenario	Gas Mix / TDT	Voyager	Abyss 120	Table
Heliox 15.9 alone	Heliox 15.9 / TDT	12:32	11:21	---
Heliox 15.9 w/EANx 50	Heliox 15.9	00:28	00:23	---
	EANx 50	01:46	01:58	---
	TDT	02:14	02:21	---
Heliox 15.9 w/EANx 50 & EANx 80	Heliox 15.9	00:28	00:23	---
	EANx 50	00:24	00:37	---
	EANx 80	01:05	01:07	---
	TDT	01:57	02:07	---
Trimix 14/54 w/EANx 50 & EANx 80	Trimix 14/54	00:14	00:16	---
	EANx 50	00:30	00:30	---
	EANx 80	00:45	00:54	---
	TDT	01:29	01:40	---
US Navy Protocol	Heliox 12.9	00:17	00:15	00:14
	Heliox 50	00:41	00:39	00:49
	Oxygen	01:01	01:12	01:27
	Air Breaks	00:00	00:00	00:10
	TDT	01:59	02:06	02:40
DCIEM Protocol	Heliox 16	00:03	00:07	00:03
	Air	00:27	00:36	00:36
	Oxygen	00:43	01:05	01:21
	Air Breaks	00:00	00:00	00:10
	TDT	01:13	01:48	02:10

Using the Abyss 120 algorithm does extend the required decompression time compared to the Voyager software except in the heliox 15.9 only profile, where the decompression time was reduced by 1:11 minutes, but still was too long at 11:21. The only profile where the extension of the decompression time was greater than 15 minutes was the DCIEM protocol. The required decompression time for Abyss 120 was 35 minutes longer than Voyager, but still fell 22 minutes short of the DCIEM TDT. These results do not significantly change the outcome of the evaluation and, barring a technique to be able to adjust the NiTek HE's level of conservatism, do not indicate the need to modify the recommendations and conclusions presented in the main body of this paper.