Just as with tables divers have to understand how to use a computer. They have to read the instructions, look at the computer regularly and understand the displays of the particular computer in use.

Computers, because they require less thought, are less likely than tables to be misued when a dive profile inadvertently forces the diver to recalculate his or her remaining no-stop time underwater.

Those which integrate air consumption with the dive profile can help divers avoid running out of air.

For consideration

Given the well documented inability of many recreational divers to calculate tables properly, or maintain a predetermined depth and the lack of evidence that computer algorithms, rather than the way the computer is used, influence the DCS rate when care is taken to dive sensibly, there is a strong, if expensive, case for teaching all diving students how to usea computer rather than continue to fail to teach them how to use tables correctly.

Finally, anyone thinking of buying a computer should read Dive Computers, by Loyst, Huggins and Steidely,[21] to see which comes nearest to their ideal, before buying. A new edition will be available towards the end of 1994

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COMPUTER ASSISTED DIVING: ARE YOU IN CONTROL, OR IS THE COMPUTER?

Drew Richardson

Electronic dive computers are revolutionising recreational diving. Dive computer use has boomed from a decade ago, when it was rare to see one. Today, there are more than 16 models, and at least eight different types of dive tables. For the first time, U.S. Navy (USN) dive table use is declining and special application table and computer usage is increasing. Computers now enjoy widespread popularity amongst divers of all skill levels. The age of dive resort travel and live-aboard diving, coupled with dive computers, has established a trend towards more dives per day for several consecutive days.[1]

Dive computers are valuable tools, offering a number of advantages over standard tables. They free divers from the complexity of table calculations, and allow them to perform multi-level dives safely. Dive computers can replace both the standard timing device and the depth gauge. Since most dive computers begin timing dives and surface intervals automatically, they eliminate the hassle of using traditional timing procedures. Compared to standard analog depth gauges, dive computers are generally much more accurate and reliable. Many new dive computers provide rate of ascent information. Computer multi-level diving allows longer bottom times than those permitted by standard tables planned for one depth dives. Computers provide computerised, real-time, continuous dive profile data while under water and most importantly, the no-stop time remaining.

Used conservatively, these devices can promote safety; used aggressively, they may increase risk. Problems can arise if divers use computers incorrectly, or place complete, but unsupportable, faith in their ability to prevent decompression illness. Some individuals believe computers are infallible, and push computers to their absolute limit, over and over again. Other divers use computers without understanding their limitations. Fortunately, responsible divers understand the limitations of computers, and dive accordingly.

Divers need to understand how dive computers generate numbers, and what the limitations are, if they wish to dive conservatively assisted by a computer. Decompression decisions must still be part of pre-dive planning and post-dive information recording. The term “computer assisted diving” refers to the process of pre-dive planning, proper dive habits and post-dive follow up. A dive computer assists in making decompression decisions while underwater, however, the diver should develop and follow a dive plan that includes anticipated depth and bottom time. Let us explore a few points that help divers take control of their dives.

Decompression illness is a random occurrence

Tables and computers, no matter how well designed or how well tested, are simply mathematical models that approximate how the body absorbs and eliminates an excess of nitrogen. Avoiding decompression sickness (DCI) is a statistical phenomenon. It is impossible to design a device that is 100 percent safe, for 100 percent of the people, 100 percent of the time. Because people differ in their susceptibility to DCI (i.e. individual variations), no dive computer or table can guarantee that decompression sickness will never occur, even when diving within the table or computer limits. Divers who find this unacceptable and wish to avoid completely any risk of decompression sickness, have essentially three options:

1 Never surface from a dive.
2 Never dive in the first place.
3 Never go to altitude.

Humans are different from computers

There is a gap between computer modelling and human physiology. While decompression computers and tables spring from straight forward mathematical computation, the dynamics of nitrogen uptake and elimination within the human body do not follow these formulae. There is a wide range of variables within human physiology which affect how quickly the tissues load nitrogen to equilibrium:[2]

The blood supply of the tissues.

Solubility of the gas and the tissue relative to its solubility in blood.

Diffusion, the rate at which gas travels through the tissue.

The gradient between ambient and tissue pressures which provides the driving force for diffusion.

Temperature of the tissue. This influences gas solubility, diffusion rate and regional perfusion.

Local energy consumption, which is related to work load. This influences the partial pressure of CO_2 and regional perfusion.

The partial pressure of carbon dioxide in the tissue, which influences regional perfusion.

Unknown factors (physiological factors at play yet to be identified).

The relationship between these processes complicates the ability of a table and computer to model gas exchange effectively. The reasons are many, but include the fact that perfusion in parts of the body is intermittent. While gas elimination rates are influenced by the above processes, elimination is actually slower than gas uptake. Most decompression schedules and models, however, assume that elimination mirrors gas uptake. The majority of decompression tables and computers on the market today are based on gas uptake primarily being influenced by tissue perfusion and by the solubility of gas and tissue.[2] Exceptions are the Royal Navy, Royal Navy Physiology Laboratory (RNPL) and BSAC decompression schedules, which consider diffusion to be the rate limiting process. Most tables use a perfusion model because it is easier to calculate, and because, within limits, it reproduces the outcomes of manned tests and field data.

Mathematical calculations are further complicated by bubbles or gas phase separation. Formation of bubbles reduces the gradient for gas to diffuse out. While this complex processes is largely understood, it cannot be effectively combined into a practical, workable mathematical model. This leaves a gap between what is understood and what is effectively modelled.

Computers have operational limits

Computers are not fool proof. Environmental conditions and the random nature of recreational scuba diving can result in unexpected dives that perhaps the model and design were never intended for.

Divers compound these difficulties, and create more, by ignoring their training, their table or computer, acceptable safety rules or appropriate dive patterns. All of these variables pose problems for decompression design and schedule validation.

Multi-level diving

Multi-level diving theory is just that: a theory. Until the Powell/Rogers DSAT test established an empirical basis, little test data existed. To understand the practical and safety limits of multi-level and repetitive diving, it is helpful to have some basic understanding of mathematical decompression theory. Several excellent sources exist on this topic.[2,3]

Multi-level diving in practice is a technique for extending bottom time beyond the no-stop limit for the deepest depth of the dive profile by ascending to shallower depths. Decompression theory tracks decompression status throughout the dive by calculating nitrogen absorption and elimination in theoretical mathematical compartments. These compartments are adjusted to specific nitrogen loading limits established by the table or computer designer.

J S Haldane originally divided the body into five compartments in his work. The USN later used six compartments in the popularised version of the USN dive table. Today some dive computers and tables use 14 or more compartments. Compartments differ from one another in two ways. They each absorb and release nitrogen at different rates (half-times) as set by the designer, and they can tolerate a different maximum amount of absorbed nitrogen called "nitrogen loading." The table designer then establishes no-stop limits through experimental test dives to establish or allow more nitrogen loading.[3]

A significant limitation of decompression theory is that it cannot account for variation in individual diver physiology, such as age, weight, gender or variation in predicted dive patterns.

What is a dive computer

A dive computer is basically an electronic calculator. All use an electronic mathematical model telling the computer what to do with depth and time information. This mathematical model or algorithm differs between brands of computers. The primary purpose of a computer is to tell a diver when he has reached a no-stop limit, so he can stay well within it. They all display depth, no-stop time remaining and elapsed bottom time.

On the whole computers are accurate depth gauges and timing devices. Tests have shown computers to be extremely accurate depth gauges being correct to within 0.3 m (one foot) at a depth of a 30 m (100 feet).[3] Some are calibrated for fresh water and read approximately three percent deeper than the actual depth when used in sea water.[3]

Dive computers have performed well when measuring time in tests.[3] One of the main advantages for the dive computer is that it knows both depth and time accurately and simultaneously.

Dive computers on the market today offer a variety of additional information in many different forms. Although dive computers come in a variety of sizes and shapes, they are all basically the same. All dive computers contain a micro-processor/computer, which is activated by a renewable power source (battery). It contains an analog to digital converter (A/D), read only memory (ROM) and random access memory (RAM) to store and calculate data and provide scrolling. All dive computers have a pressure sensor to read the depth and a timing device to read the elapsed time. This information is processed by micro-processor, using a decompression algorithm, and information is shown in the display for the diver to use.

Dive patterns

The variability of risk for decompression illness varies with the type of dive performed. The 1992 Divers Alert Network (DAN) report on Diving Accidents and Fatalities states that in 1992 slightly less than 50% of divers with a decompression illness were using computers on their dive.[4] In 1992 more than 80% of the divers who used computers and suffered decompression illness made multi-level, repetitive dives to depths greater than 24 m (80 ft).[4] Table 1 is from the DAN report and lists the factors affecting divers who used computers and suffered decompression illness from 1987 to 1992.[4] The highest incidence levels were with deep dive profiles, repetitive diving, multi-day diving, multi-level diving and divers doing dives that required staged decompression.

Differences between calculations

Tables and computers often give different numbers, which causes confusion on dive boats between user groups. The allowable bottom time sometimes varies widely for the same profile with different tables and computers. Many individuals wonder why these times vary, and controversy results. A simple explanation is that the numbers differ because of differences in the intent and design assumptions made by various table or computer designers, and because a computer mathematically interpolates precisely, while a

TABLE 1

FACTORS ASSOCIATED WITH COMPUTER DIVERS SUFFERING DECOMPRESSION ILLNESS 1987-1992

Year	1987	1988	1989	1990	1991	1992
Computer divers with DCI	n=41	n=84	n=126	n=203	n=194	n=224
Factors analysed	%	%	%	%	%	%
Repeat dive	73.2	80.5	73.0	82.3	87.4	84.4
Fatigue						35.9
Within tables	29.3	44.0	26.2	27.6	24.6	60.3
Deeper than 24 m (80 ft)	92.7	82.0	81.0	85.7	80.4	77.7
Single day	48.3	45.5	48.4	51.7	54.3	47.8
Current	43.9	42.9	44.4	52.2	47.2	47.3
Multi-day diving	51.7	54.5	51.6	47.8	45.7	52.2
Multi-level diving	56.1	58.4	68.3	67.5	80.4	91.1
Exertion	34.1	26.2	31.0	29.6	56.8	58.1
Outside tables						39.7
Decompression dive	48.8	36.9	20.6	27.1	25.1	25.9

Figures taken from reference 4.

table rounds off coarsely.

The conservatism of tables and computers, and the safety of divers using them are not one in the same. Safety is a real-world phenomenon; it is observed and measured. Safety is not determined simply by a computer or numbers in tables. If it was, the more conservative numbers would be safer, which would equal better. If this mindset was adopted to the extreme, the so-called "best table" would simply prohibit diving.

Tables and computers are not the sources of decompression knowledge, but the application of it. In determining what is best, it is important to evaluate clinical and field evidence, and to accept the fact that differences in decompression systems do not necessarily make one safe and the other unsafe.

Computer algorithms

There are concerns surrounding computer use and the lack of testing of the algorithms used. The USN tables were borrowed by the recreational diving community and performed very well, considering they were never designed for recreational diving. Recreational diving patterns have changed quite a bit in the past several years.

Exotic dive travel creates the incentive for divers to try to get their money's worth by maximising the number of dives they do on holiday. This has resulted in multi-day repetitive diving becoming a standard practice on live-aboard boats and at many resorts.[1] Legitimate questions arise in attempting to answer the question "How much diving is too much?"[5] From a scientific standpoint very little is known about this type of diving with regard to an increased risk of decompression illness. Computers are number crunchers, not physiological monitors. They do not adjust their calculations for age, physical condition, dehydration, blood alcohol level, water temperature, strenuous diving, fatigue, etc. The diver must do that. He or she is not helped by the fact that only a few dive computers allow the user to add safety factors to the program.

Concerns over anecdotal evidence of computer using divers developing decompression illness generally arise from computer dependent diving, where there is an absence of pre-dive planning and post-dive information follow up. This type of diving shows inattention to detail, laziness or ignorance. The marvels of electronics lull some individuals into a false sense of security.

Computers increase the temptation to avoid planning scuba dives, despite the fact that dive computers will give information, in a very logical format, which conflicts with common sense and safe diving practices. For example, a dive computer will give information about the no-stop limit for a deep dive following a long shallow dive, even though doing dives in this order violates standard safe diving practices. While there is no such thing as perfectly safe diving, the question becomes, "Which behaviours reduce the incidence of decompression illness to acceptable levels?"

Good Computer Habits

Here are ten simple things to remember for developing good computer assisted diving habits.

1 The acronym, DATA, has been suggested to avoid the mistake of not monitoring instruments and gauges during a dive and to be responsible for oneself.[6] D stands for depth, a diver should know how deep he is now, and what the maximum depth was he obtained during his dive at any given time on the dive. A stands for air, a diver should know at any time on the dive how much time he has remaining. T stands for time, the diver should know how long he has been down and how much of the planned bottom time remains. A stands for area, where the diver is in relation to the exit point. This simple acronym DATA may go a long way in reminding the diver to observe the necessary parameters for computer assisted diving.

2 Divers should listen to the dive briefing and ask questions about the local dive, site and its environmental variables.

3 A diver using a computer should know how it works and remember that it is a tool. Divers should begin by reading the instructions for the model they are using. If a diver does not understand tables, he will not comprehend the significance of computer displays. Some individuals do not read the instruction manual, and this is frequently true when the computer is hired.

4 Divers should use the computer as a no decompression stops device. If a diver's bottom time is not limited by air, he should avoid pushing the computer to its no-stop limits. Running a dive computer down to zero no-stop time on each stage of a multi-level dive, or on repetitive dives, bypasses all the safety factors built into square dive calculations in tables. Divers should avoid mandatory stage decompression, slow their ascents and take a safety stop.

5 A diver needs to understand there is no such thing as perfectly safe diving, and that diving behaviour affects the risk of decompression sickness. There are still far too many cases where divers abruptly run out of air for lack of monitoring depth, time and air profiles underwater. There are nine air pressure integrated computers that predict air supply limits, in addition to no-stop limits. They have the ability to show the diver the shorter factor limiting the dive, air or no-stop limits.

6 Buddies should use their own computers and terminate the dive together following the more conservative computer in the team. They should never share a single computer.

7 Divers need to understand the display, but not accept numbers on blind faith. Rather, they should be used as a guide relative to the diver's physiology.

8 Divers need to plan dives and monitor their progress during the dive. Safe diving guidelines, such as no saw tooth diving, planning deeper dives before shallow dives, avoiding repetitive dives deeper than 30 m, need to be followed.

9 Responsible divers stay fit, drink plenty of water, sleep well, do not drink alcohol immediately before diving, do not dive when not feeling well or with an illness, and avoid strenuous exercise before, during and after diving.

10 Divers should have a back up plan in the event of computer failure.

Conclusion

Computers are valuable tools and offer a number of advantages over tables. They can replace the standard timing device and depth gauge and reduce the hassle of traditional timing devices or procedures. They can provide rate of ascent information, thus allowing divers to slow their ascents. They remove human error from calculations. They permit multi-level diving, allowing longer bottom times than those permitted by standard square wave tables. Multi-level diving with a safety stop may be less stressful, from a physiological standpoint, in the production of gas phase separation than square profiles. Computers provide computerised real-time, dive profile data while underwater and most importantly, identify the maximum no-stop time remaining.

Nevertheless, a diver's brain is perhaps the most important computer on the dive. The brain, using good common sense and a safety conscious attitude, can do more than dive computers to avoid decompression sickness.

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