In the event of a computer failure during a no-stop dive, and, in the absence of an appropriate back-up, ascend slowly to around 6 m and spend at least five minutes there before surfacing. If a mandatory stop(s) was indicated before the computer failure and you cannot remember it, spend as much time at around 6 m as possible (unless deeper stops were previously indicated), leaving enough air to return to the boat safely. Do not re-enter the water for at least 18 hours, or for the time needed for the dive computer to totally off-gas (had it not malfunctioned), whichever is longer.

If using a dive computer for multi-day, repetitive diving, take a break around the third day to allow your body to rid itself of some of the extra nitrogen load it has accumulated.

Do not begin to use a dive computer if you have dived in the previous 24 hours.

Ensure you are well hydrated before and after diving.

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WHAT I LIKE AND DON'T LIKE ABOUT DIVE COMPUTERS

John Knight

What do I like about dive computers ?

The one word answer is convenience. They save the diver from decompression table calculations during a dive. Divers often go below the planned depth and so need to calculate an new dive or decompression time under water.

Tables were originally developed for naval diving. The divers were puppets manipulated by a puppet master, the dive superviser at the surface, who controlled their every movement. He did the decompression calculations. The diver's depth was known to the supervisor and the divers usually stayed at one depth. Such disciplined divers do not have to think about tables while underwater, they get told when to come up and when to stop on the way. This is not the way that recreational divers dive !

Few recreational divers do square dives. All decompression theories allow multi-level dive decompression requirements to be calculated. Using tables to do this is complicated and requires thought underwater. Even with the PADI Wheel thought, manual dexterity and accuracy are required. Complicated thinking is more difficult and less reliable under water than it is on the surface. Dive computers perform automatic calculation of the dive profile and of the estimated nitrogen load during the dive and of the remaining no-stop time.

A dive computer allows one to do a multi-level dive without having to worry about whether one has ascended the right amount to suit whatever multi-level dive one is allowed by the tables. The computer does the calculations. A relatively safe no-stop dive can be done by going deep first and well before the no-stop time for that depth is reached on the computer, going shallower and repeating the process again and again.

Another reason for using computers is that recreational divers are bad at using tables. In 1988 I asked those attending the SPUMS Annual Scientific Meeting to do a short test on the tables.[1] Less than half (19 out of 50) of those who collected a question sheet returned it and only ten got every answer right.[2] This bore out a report from America[1] which showed that only 19% of a group of commercial divers and instructors could get the answer right. In Queensland 45% of divers tested answered the first question correctly and only 36% got the second right.[3,4]

It is quite clear that trainee divers are not taught to use the tables thoroughly enough so that they remember how to use them after months without diving. Tables are relatively easy to use for a single dive. Many divers get into trouble calculating the second dive time. People have trouble with the concept of residual nitrogen. With Nu-way and similar tables showing available time and residual nitrogen time in different colours people often pick the wrong colour numbers.

In fact recreational divers are so bad at using the tables that many dive charter boats in Australia have a divemaster who calculates and announces every diver's second dive time just to be on the safe side ! During the last few years in Victoria the increased use of dive computers has made this calculation unnecessary for a growing number of divers.

A third reason for liking computers is ease of use. First one has to read the instruction book to find out what the display shows. Although all computers display the current depth, time underwater and no-stop time remaining there is no standardisation of which figure goes where. But once one has found this out one can dive safely, at least for the first dive.

The elapsed dive time and the time to a no-stop limit are usually displayed. This quite definitely is an improvement on using the tables and suddenly finding, when you look at the maximum depth indicator on your depth gauge that your 18 m dive had turned into a 21 m dive without you realising it.

Algorithms

Tables and computers are only as good as the algorithm that they are based on. Uptake and elimination of gases are modelled with equations, usually representing the body as a series of compartments that fill up with gas at different rates. In most tables gas is assumed to be excreted at the same rate as it went it. Anaesthetists have known this to be untrue since the early 1960s. Only relatively recently has this been accepted by the diving community. However, for single dives it does not seem to matter what the mathematics are as long as they result in initial no-stop limits close to, but not exceeding, those of the USN. The British Sub-Aqua Club/Royal Naval Physiological Laboratory (BS-AC/RNPL) tables treated the body as one compartment while the United States Navy (USN) tables used many compartments. But the no-stop limits were very similar. The new USN probability of decompression sickness (DCS) tables are based on a two compartment model which was a "best fit" for USN DCS results, while all the dives were done using a multi-compartment table. The Defence and Civil Institute of Environmental Medicine (DCIEM) tables use 4 compartments and are based on the results of many years of experimental diving at DCIEM and with the Canadian Forces. They have been continuously modified since they were first issued in 1983.

A few early computers "looked up" existing tables. Most computers use table algorithms to calculate the nitrogen load at frequent intervals. Different brands of computers use different algorithms. Many are based on the Spencer no-stop limits model as modified by various developers and others are based on Bühlmann's Swiss model. The latter tend to give shorter bottom times.

In practice it does not matter which table is marginally safer for the diver unless the diver uses it properly. Simplicity makes using a table correctly easier. The DCIEM tables have 2 sides and a separate multiplication table. The BS-AC 1988 tables have 7 sheets to look up depending on surface intervals, depths and number of dives. The PADI wheel can easily be misaligned.

The only table that requires no calculations is the Bassett tables formatted by John Lippmann and myself. It was designed for a diver to put a finger on a number and get the answer by sliding the finger along a line either vertically or horizontally or both. It also has three fudge (safety) factors built in for the first dive and five for the second compared with the USN tables.

Safe use of tables and computers

Whether a diver uses tables or computers there are certain basic steps needed to dive safely.

To use any table properly one has to know how to use it. Unfortunately many divers do no know. Then one has to know the maximum depth of the dive, which with recreational divers is seldom the planned depth of the dive!

Going deeper than planned should mean recalculating the no-stop dive time, or the decompression required, during the dive. In my experience, except when using the Bassett tables, this exercise often turns out to be on a par with solving a cryptic crossword clue. The Bassett tables require no thought, only the movement of a finger horizontally or vertically, to find the new time.

Many Bourdon tube depth gauges are inaccurate. Some are safe because they read deep but as many are dangerous as they understate the depth. Very few divers have their depth gauges checked frequently. On the whole dive computers have relatively good time and depth sensors.

To use tables one needs to know the time underwater. Who here has never forgotten to set the watch bezel at the beginning of a dive ? I bought a Citizen Aqualand because it turns itself on, when in diving mode, and will beep at me if the depth or time that I have set is exceeded.

Ascent rates are important. It is difficult to maintain 18 m/minute or less using a watch and depth gauge. A computer with an ascent rate alarm, especially with both audible and visual alarms, makes it much easier.

Computers

Dive computer manufacturers and distributors claim that their computers are more conservative than the USN tables for single no-stop rectangular profile dives. Studies support this, but there is a wide variation in no-stop bottom times between various computers.[5,6] However, this apparent conservatism is lost once the dive profile becomes multi-level and does not apply to repetitive dives.

The first computer to have mass sales was the Orca Edge. It has a very convenient graphic display which darkens from the top as one goes deeper and from the left as one stays underwater. This shows its calculation of nitrogen uptake and excretion. It displays the diver's depth, bottom time and Spencer-Huggins no-stop time remaining in figures. By ascending when the dark area of the array nears the no-stop curve, or keeping away from the edge, it is easy to manage a no-stop dive. Safety factors can be added by keeping an extra pixel or two from the curve. It will tell the diver that it is time to ascend and the depth to which he or she must rise to do any decompression stop. It will tell the diver how long to stay at the decompression stop. Of course it has its drawbacks. One is that it weighs a kilo and another is that will allow dives that are dangerous such as diving to 30 m for 10 minutes without a stop, have a one hour surface interval, dive again to 30 m for 10 minutes, again without a stop, have another hour surface interval, dive to 30 m for 10 minutes, again without a stop, and so on.[5] Leakage was a significant problem with some models of Orca computers.

Many people, myself among them, have reservations about the algorithms of computers which allow such dives. When the Edge, Skinny Dipper, Delphi (all made by Orca) and Suunto SME-ML were tested to see if it would allow a series of "bounce" profiles, known to produce DCS, they were shown to permit them.[5,7] They also allow, without decompression penalties, diving deeper than the first dive on the second and later repetitive dives.

Most computers switch on automatically when contacts are wetted. But most have to be in the air for a period of time for the computer to run through its internal checks or it refuses to work underwater. The Beauchat Aladin Pro and Suunto Solution, which have different algorithms, do not require these in the air checks.

Air integrated computers, which monitor cylinder pressure, turn themselves on when the air is turned on and display of cylinder pressure with or without remaining air time at that depth. I have been using an Apollo cylinder pressure and depth gauge, which also times the dive and surface interval, for some years. It also displays the remaining air time. I have had some very odd remaining air times depending on my breathing pattern, but I do like the graphic of the emptying tank. Air integrated computers should make it more difficult to run out of air unexpectedly.

The latest generation of dive computers comes in two parts, a pressure monitor with a built in radio transmitter, which allows the high pressure hose, and the contents gauge on the end of it, to be eliminated, and the wrist worn computer which presents all the information including air status. This eliminates the problem of a high pressure hose blow out but could introduce new problems. Time will tell. Only one computer in this configuration is actually on the market. It is sold as Cochrane, Sea Hornet and Mares. There are rumours that there have been various teething troubles. The Uwatec Air-X is being advertised widely but is not yet available (May 1994).

Risks of using computers

Whether dive computers increase or decrease the risk of decompression illness is a question that is unlikely to ever be answered, because the number of dives performed with computers or tables is unknown and never will be known for certain.

As computers become commoner there is little evidence that they are dramatically worse for divers. There is no firm evidence that either dive computers or tables are safer than the other.[8-12] Much the same as for cars. It is the diver misusing the diving aid that is usually at fault.

The incidence of decompression sickness reported by the BS-AC[13-16] appears to have been distributed between table and computer users in approximately the same proportions as their users over the past few years.

There is evidence that many dives can be done safely with properly used computers, giving a lower incidence of DCS than in table users diving the same dives at the same time.[17] The snag is that one cannot tell whether a table user has used it properly, while the mainly Microbrain computers used on board the *Ocean Quest* gave the dive profile which could be checked. Some have criticised this paper on the grounds that the diagnosis of DCS was made by non-medical people. Realistically most sufferers from decompression illness have the diagnosis made by another diver and later confirmed by a medico. In naval and commercial diving the confirmation often comes after treatment has started.

Advantages of dive computers

With computers some of the snags with table use are abolished.

On the whole dive computers have relatively good time and depth sensors.

Most computers turn on as the diver enters the water.

Once one knows how to use the model one is using, computers are easier to use than tables underwater. The calculations are done by the machine, not by a slightly narced and poorly trained diver, so error is reduced.

A some computers can play back the dive profile and a few allow this to be fed into a computer for permanent storage and retrieval so allowing a data base to be accumulated.

Most also display the no-stop profile available for the next dive.

Disadvantages of dive computers

Many divers have blind faith in their computers and assume that following the computer will always be a protection from DCS. This is no more true of computers than tables.

The diver has to think about the safety factors he or she wants to add because of age or physical status. These can be easily factored in with tables, but only computers which have an altitude mode, which can be used at sea level to reduce the allowable nitrogen load, allow safety factors to be added to the program. However never letting the no-stop time drop below 5 or 10 minutes adds fudge factors.

The problem with computers is the calculations done inside the computer. The longer dive is available because the computer calculates off-gassing as the diver nears the surface and so allows a longer no-stop limit. Unfortunately no one knows whether the program which is calculating nitrogen uptake and loss is correct in its assumptions. All computer users, and the users of many tables, are effectively guineapigs testing the mathematician's figures.[18] Some have come to harm as their physiology did not reproduce the physiologist's guesses. Some of the models have been altered, without much publicity, to get rid of embarrassing DCS figures.

Some of the repetitive dives allowed by some computers will quite definitely bend some people. So did some of the dives in naval tables when they were first tested in the sea after being safe in the chamber. Some dives in the USN tables are known to be less safe than the majority, and this is coped with by the Master Diver adding fudge factors of time and depth before working out the decompression requirements.

Some dive computers have fussy faces with more than one set of information being presented in the same place. If not presented clearly this can lead to problems as can having information in different places on different computers.

Some computers have been designed to stop working if the diver goes too deep or goes into decompression time. Usually the depth and time displays remain working but decompression information is not displayed. One wonders what the diver is supposed to do to get back to the surface safely if the depth and time displays have vanished. Unless he brought along a depth gauge, watch and tables, which is recommended on page 3 of the Suunto Solution instruction book (but not in the Aladin Pro, the other widely sold dive computer, manual), he or she is paddleless in the proverbial barbed wire canoe. Some computers that will bring you back to the surface refuse to work for 24 hours after a depth or decompression violation. Then they are available to the diver again but have erased all previous nitrogen loads. I wonder how many divers would do the next day's diving using borrowed tables, I am sure that some would. The Suunto Solution and one dive computer under development will return the diver to the surface after a depth or decompression violation, but will not display again until it has calculated that the diver has off gassed all of the nitrogen load.

Computers are expensive, so there is a higher profit for the dive shop in selling a computer rather than tables, which could lead to pressure to buy.

They are advertised as being safe, but with no mention of the disadvantages such as untested algorithms, shut downs and the possibility of breakdown, nor of the need to allow fudge factors. In one survey 33 out of 144 computer users had experienced a computer failure.[19] The Aladin Pro appears to have been the most reliable to date. Rumour has it that the Oceanic computers are over represented among failures.

As with tables, the computer cannot predict the wearer's physiology or physical status, nor the circumstances of the dive. There is no substantial safety margin incorporated in many decompression algorithms. Only a few more recent model computers include some safety margin buffers. On the other hand, tables require the use of "rounding up" of any intermediate depth and time and so usually allow some compensation for the body's deviation from the decompression model.

No computer available at present appears to have undergone extensive testing and most have been released without any substantial and documented controlled testing. To be blunt computer divers are guineapigs testing the safety of the computer's algorithm every dive.

For repetitive diving dive computers are generally considerably less conservative than most tables. Repetitive dives have been shown to be a significant factor in increasing decompression sickness (DCS) amongst divers, whether using tables or computers. Divers Alert Network (DAN USA) data indicate that 64% of the divers treated for DCS in the USA in 1987 had become ill after repetitive dives.[8] This increased to around 80% by 1990.[12] The increase may be due in part to divers' attempts to maximise dive time using decompression systems such as computers and the Repetitive Dive Planner (RDP).

Approximately 44% of the divers treated for DCS in the USA in 1990 had been using a dive computer.[12] It is possible that nearly 45% of American active divers used computers at that time as a 1992 survey of 265 experienced, adventurous, mostly American, divers showed that 81% used a dive computer.[20] But diver statistics are unreliable, as an active diver is often defined as one who does one dive a year. A very large study indicated that certain dive computers can be used safely if they are used intelligently and if safe diving practices are observed.[17]

At present the algorithms of most current models need to be altered to give more conservative times when the computers are used for deep repetitive dives, multi-day diving, and multi-level dives of increasing depth. Some computer manufacturers have already modified, or are currently in the process of modifying, their algorithms to try to be safer with, or discourage, such undesirable profiles.

Desirable features

I think that the ideal computer should turn itself on when the diver enters the water, show air status, depth and maximum depth, dive time, no-decompression limits for that depth, decompression status, stop depths and times and be easy to read with big numbers for aging eyes.

I would like graphics for depth, no-stop limits, with a warning zone, and air consumption.

My ideal computer should have a diver control to add fudge factors. Early in 1994 only three, including the Suunto Solution, allow the diver to select an altitude mode (a fudge factor) which reduces allowable dive times. None allow the diver to do more than this. It should be possible for the diver to add as many safety factors as he or she wants.

It should have an audible warning when a pre-selected depth is reached. No current computer does this.

It should give audible and visual warning of a rapid ascent rate and of missed decompression and allow the diver some time, say a minute, to take corrective action before entering "violation mode". This feature is available in a number of computers. When the computer registers a "violation" it should continue to display the decompression requirements for that dive before shutting down.

Its algorithm should add decompression penalties for going deep late in a dive and for repetitive dives as deep or deeper than the previous dive. It should also reduce the calculated rate of inert gas elimination if the diver yo-yos or ascends too fast, as these activities are likely to increase bubbling and so slow down gas elimination.

All dive computers should display depth, maximum depth, time underwater, remaining no-stop time and air supply in the same places on their faces. It has been suggested that this would limit innovation but standardising the position of brake, clutch and accellerator pedals in the 1920s did not slow down improvement in cars.

The computer should remember at least the last 10 dives and surface intervals. This information should be able to be accessed by a personal computer.

Conclusions

Divers must be taught the principles of how to avoid decompression illness. Some divers fail to follow the safe diving practice of doing the deepest dive first.

Both tables and computers require that the user knows how to use the aid properly. Many divers do not know how to use the tables properly.

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