day's diving I usually take my regulator and computer back to be rinsed in fresh water. I carry a spare battery, and change the battery regularly.

One problem is, if I am diving with a partner who is not familiar with my computer's display, the buddy does not appear to understand it. A computer display can be a little confusing if not seen before. This is especially important with the wide variety of models on the market, and the number continues to increase.

I also like the concept of multilevel diving, especially on SPUMS trips. At home in Melbourne most of the diving is square profile. I have tried a PADI Wheel and even had lessons on how to use it from Ray Rogers. However it is much easier to use a computer, as it makes multi-level diving a breeze and diving more enjoyable.

The ability of computers to log previous dives, makes completing log books easier and enables divemasters to check dive profiles. Divers presenting with diving related medical problems can retrieve their dive log from the computer. In the near future more computers will allow details to be down loaded onto a PC. At least one major supplier of dive computers is planning to supply hyperbaric units with free interfaces to suit its computers.

In the near future there will be even more models of dive computers on the market, with interfaces to down load dive details and user modifiable parameters, i.e. the user can make the unit even more conservative. Some newer models are programmed to compensate for water temperature and diver work. One manufacturer even proposes a head-up display in a scuba mask. One model now allows for software upgrades.

After discussions with a variety of dive shop proprietors it is clear that a large number of divers are buying computers and not dive tables. They dive shop owners feel that in the not to distant future only computers will be sold.

In the future we will have computers controlling rebreathers, and one manufacturer is considering a wrist mounted GPS (global positioning system) unit to replace the compass.

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DIVE COMPUTERS

John Lippmann

Some of the newer "multi-level" tables include methods for compensating for parts of a dive spent shallower than the maximum depth. However, the ideal situation is to have a device that tracks the exact dive profile and then calculates the decompression and air requirements for the actual dive.

In the early 1950's, the United States Navy formed a committee to identify equipment modifications and improvements that were necessary to accommodate the newly introduced scuba operations. The committee published a report which incorporated a design of a diver-carried analogue computer which simulated nitrogen uptake and release in two theoretical tissue compartments. It also discussed what it described as the "Ultimate Gauge," an electrical analogue device which would indicate both the decompression and air consumption status of the wearer so that the diver would know if he had enough air to complete any required stops.[1]

Decompression meters and dive computers began to appear around the mid-1950's. Probably the best known of the early devices is the *SOS decompression meter*. This unit was designed in 1959 and is still commercially available today. It incorporates a ceramic resistor through which gas is absorbed and released. The pressure built up inside the unit would determine the required decompression.

In the following years, various organisations including Farallon, DCIEM and others experimented with a variety of pneumatic, electrical and electronic decompression calculating devices. By the mid-1970's, with the advance in microprocessors, it became possible to construct a relatively small computer capable of doing multi-level calculations.

1983 saw the release of two microprocessor computers which were specifically designed for recreational divers. One was the *Decobrain,* produced in Switzerland and the other was the US produced *Edge*. These initial units were large, relatively expensive and prone to problems. Improved technology has overcome some of the early technical restraints and over past several years we have seen the introduction of affordably priced computers that offer more accurate depth and time recording, together with multi-level decompression calculations.

Some early dive computers had decompression tables programmed into their memory and read the tables to give the diver appropriate decompression information. However, most dive computers are programmed with a decompression model, rather than a set of tables. The current generation of computers are based on various derivations of either the Bühlmann (ZH-L) system or a modified US Navy system.

Dive computers offer the diver a number of advantages over the tables, which include:

1 Eliminating the problem of divers making errors in their decompression calculations since the computers do the calculations automatically and accurately in accordance to their model. Divers commonly make mistakes when using dive tables.[2,3,4]

2 Allowing the diver much more dive time on most dives, especially repetitive dives since computers use the actual dive profile, rather than just the maximum depth, and account for a variety of tissues compartments, rather than a single tissue compartment during a surface interval as most tables do.

However, some people remain critical of these devices. Some argue that a diver will become too machine-dependent, forgetting or never learning certain basic principles of safe dive planning. Probably the main criticism centres around the fact that there have been too few well-controlled, documented tests to determine the validity of multi-level and multiple repetitive dive applications of the various models used by the computers.

The decompression models programmed into the computers are designed to simulate nitrogen uptake and release in a diver's body. Most assume that nitrogen uptake and elimination both occur exponentially. Most early dive computer algorithms assumed that uptake and elimination occur at the same rate and some still do.

Gas kinetics within a diver's body depend upon a variety of factors which include perfusion, solubility of the gases, and diffusion. Factors such as exertion during the dive, carbon dioxide levels and temperature complicate the process, and once bubbles have formed the process becomes even more difficult to predict. Although certain algorithms still assume identical rates of uptake and release, several programmers have now attempted to account for a significantly slower rate of elimination.

However, these algorithms are just mathematical models; some with a firmer physiological basis than others. They cannot completely predict the gas flow in and out of a diver's actual tissues and the possibility of decompression illness (DCI).

Are computers safe ?

Over the past five years or so the market has been flooded with various makes and models of dive computer which have been marketed aggressively. Some of the advertising was, and sometimes still is, quite misleading. It has often been incorrectly suggested that computers were more conservative than tables for rectangular profile dives (ie. those where most of the time is spent at the maximum depth). Although this may be true for an initial dive, it was and is still rarely true for repetitive rectangular dives and repetitive dives cause more DCI than single dives.

Because of some of the "technocrap" included in certain advertisements, a reader could easily be mislead into believing that these magic little boxes are scientifically sound and validated. Unfortunately, they are still subject to varying amounts of intelligent guesswork.

More colourfully, divers were encouraged to get increased value for money on their diving holidays by buying a computer and so getting far more underwater time during their vacation. Some of these advertisements even provided the monetary calculations, including the relative prices per hour underwater.

In their enthusiasm, many of these eager proponents of dive computers lost sight of the fact that, in reality, very little was known about how well the various units would perform, or were already performing, in the field.

Millions of dives have been done by divers using dive computers, most of them without incident. Unfortunately, since most of these dives are undocumented, it is still unknown exactly what sort of profiles divers are doing with apparent safety.

One report, published in 1990, gives details of around 44,000 dives made using computers, conducted from a particular vessel. There was only one reported case of decompression illness in a computer-user (although others might have gone undetected or unreported), and this diver had misused his computer.[5] Most of these dives were made using a particular type of computer which utilises a decompression model which is comparatively conservative in many situations. In addition, divers appear to have been well-briefed on certain aspects of safe diving practice, including slow ascents and safety stops.

With so many apparently "safe" dives carried out by computer-users, it might appear that the computers are reasonably reliable predictors of DCI. However, as with most tables, it is difficult to determine whether it is the computers themselves that are safe, or if the apparent safety lies in how, and under what conditions, divers are using them. Since most dive profiles are not fully recorded and documented, it is not known whether or not the divers dived to the limits given by their computers. If the units are not dived to their limits then we still do not know how good the actual limits are. This is especially relevant to multi-level and repetitive dives.

From 1987 to the end of 1991, 653 cases of DCI in divers using computers have been reported by the Divers Alert Network (DAN) USA. The number of cases has increased over the years, with computer-users representing from 15% of the DCI cases in 1987, to 45% of the cases in 1991.[6] The increase is probably mainly due to the far wider usage of dive computers.

The DAN USA data indicate a trend of around 80% of the decompression illness cases in computer-users occurring after dives deeper than 24 m; and a similar rate for repetitive dives. Overall, the 1987-91 DAN data suggest that computer-users have a higher DCI incidence after deeper dives or repetitive dives than do table-users.[6]

Data of diving incidents in Britain in 1990 indicates that 34% (27/80) of the divers who suffered DCI that year had dived within the limits of their computers.[7] In 1991, computer-users represented 29% of the 100 divers treated for DCI in the UK. Analysis of the British data shows that the vast majority of the DCI cases in computer-users occurred after dives deeper than 30 m.[8]

Australian data indicate that approximately 22% of a group of divers treated for DCI in Queensland between October 1989 and January 1993 had been using a dive computer.[9] A survey conducted in Queensland during 1990 suggests that possibly 5% of certified divers in Australia were then using a dive computer.[10] No doubt the proportion of users has grown considerably since then. A 1993 survey of Queensland diving instructors indicated that 46% of the 202 respondents owned a dive computer.[11]

The data to date cannot be used to confirm whether or not dive computer use is associated with an increased risk of DCI. Increasing computer usage will inevitably lead to an increase in the percentage of computer-users represented in DCI statistics.

However, it is obvious that divers can and do get DCI while using dive computers, although the likelihood will depend, to some extent, on how a diver uses his or her computer. Sometimes DCI results because the diver disobeys the advice given by the computer (or table). On other occasions, divers have suffered from DCI after diving well within the limits of the computer (or table).

Diving practices

An analysis of the DAN DCI statistics for 1987 and 1988 showed that those divers using computers were diving deeper than those using tables.[12,13]

Interestingly, DAN USA data indicate that in 1987, 64% of all the divers treated for DCI in the USA had done repetitive dives, whether using computers or tables. This increased to 78% by 1991.[6] The overall increase in DCI after repetitive diving may indicate that more divers are doing repetitive dives. However, it may partly be a consequence of divers attempting to maximise dive time on multi-level and repetitive dives by using decompression systems such as dive computers and certain tables which are less conservative than traditional tables for repetitive diving.

There is no doubt that computers and multi-level tables have greatly influenced diving practices. Divers are certainly spending far longer underwater, especially on reef dives where multi-levelling is more appropriate. Multiple repetitive dives, previously very restricted because of table constraints, are now commonplace, especially on live-aboard dive boats. The vast majority of these divers have no apparent problems.

Computers have also helped to teach divers to come up more slowly. Most incorporate fast ascent warnings which encourage divers to slow their ascent, especially near the surface. This feature is certainly an aid to safety and a major benefit of a computer.

Computer users often do multi-level dives. Despite the lack of scientific evidence to determine the safety of most multi-level techniques, the tests that have been done as well as experience in the field and computer simulations of gas kinetics appear to indicate that certain profiles may be associated with a lower risk of DCI. It appears that working shallower throughout a dive is a sensible practice, whereas working progressively deeper during a dive would appear to carry a higher risk.

Data from dive computer usage several years ago indicated a very high incidence of DCI after dives involving mandatory stops.[12,13] This incidence appears to have dropped over the last few years.[6] This may be a result of more conservative programs of late, or it may mean that fewer divers are doing decompression stop dives using computers.

High risk dive profiles for computer-users (and in most cases tableusers) appear to include:

- deep dives, especially deep repetitive dives
- decompression stop dives
- multi-day repetitive dives
- multi-level dives in which a diver descends deeper, rather than working shallower, during the dive.

Just as divers sometimes make mistakes when using tables, dive computers sometimes fail. Appropriate precautions need to be taken in case of computer malfunction. In an Australian survey conducted late in 1992, 29% of the divers who reported using a computer had experienced a computer failure.[9] This is a very real problem that needs to be addressed by the manufacturers, and accommodated to by divers who are using dive computers. Fortunately, most failures appear to occur on the surface, rather than underwater.

Advantages of dive computers

Avoid calculation errors common with tables.

Greatly extend dive time.

Increased flexibility during dive.

Can provide visual and audible safety warnings.

Can provide an accurate record of dives.

Disadvantages of dive computers

Accuracy of multi-level limits is unknown.

Longer available dive times can increase DCI risk unless dives are conducted sensibly.

Can encourage poor dive planning.

Can fail.

Future dive computers

Armed with the knowledge gained over the past few years, those who program dive computers now have a better idea of the shortcomings of their models and some have taken significant steps to improve the safety of their products. Certain computers have become considerably more conservative in the no-stop times they allow (and decompression stop times they require), especially for repetitive dives. The programmers will continue to address more of the shortcomings of dive computers, including their current inability to alter appropriately the gas dynamics in the model in reaction to a diver participating in diving practices generally believed to be associated with a higher risk of DCI. Future models will attempt to further address problems such as very rapid ascents, deeper repetitive dives, multiple ascents, exertion and cold. They will become more "reactive" to what the diver actually does during the dive. However, it is currently impossible to address most of the shortcomings adequately due to a lack of data on which to base appropriate models. DAN USA is attempting to build a very large database from which important information about diving practices can be gleaned. Ultimately, this will enable the decompression algorithms on which both computers and tables are based to be improved significantly.

Despite all the gaps in our knowledge of DCI, and the resulting uncertainty associated with predicting its occurrence, dive computers will continue to improve in leaps and bounds in the future and will provide more and more information and advantages to the diver. They enable the opportunity to provide valuable audible and visual safety warnings of both decompression and air status and so can be used to facilitate safer diving.

There is no doubt that dive computers are here to stay. For many divers, tables have become a relic of diving days gone by. The trend will continue and eventually tables may not be taught on most dive courses. However, divers must be thoroughly educated in a computer's use so that they are familiar with the particular computer they are using, aware of the shortcomings of that computer and with the safe diving practices that should be adopted when using a computer.

Safe dive computer usage requires

A diver educated in how to dive with the computer.

A reliable, conservative computer.

Adherence to safe diving practices.

A certain amount of good luck (which is also true with tables) !

Suggested practices for using a dive computer

When using a dive computer:

Ascend slowly. Never exceed the ascent rate recommended by the computer, and generally ascend at about 10 m/minute or slower when shallower than about 24 m.

Go to the maximum depth early in the dive and progressively and slowly work shallower. End the dive with at least 3 minutes at 5-6 m. Avoid rectangular dive profiles.

Make repetitive dives progressively shallower.

Do not dive right to the limits given by the computers. The limits may not be reliable, especially for repetitive dives. Computers, like dive tables, do not cater for individual susceptibility to DCI. These factors must be considered when deciding when to ascend to the safety or decompression stop and how much time to be spent at that stop. Reduce the limits progressively more for each dive in a series of repetitive dives. This is especially important when repetitive dives are conducted over multiple days. Also reduce the limits if multiple ascents are made within a dive or if you become cold, anxious or exert yourself during the dive.

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.