CHAPTER 4-2

INTRODUCTION TO DIVE TABLES

INTRODUCTION

Diving used to be so simple. In those early years there were only a few brands and models of masks and regulators. There were no BCDs. And basic black was the color. Today, the diver must literally sort through scores of masks, fins, snorkels, regulators, BCDs and diving suits. Once the diver determines the make and model, fashionable color coordination may also be considered in final equipment selection.

The selection dilemma is not just limited to diving equipment. Considering that the average individual dives only 10 days per year, it is possible to use a different decompression table or device for each day. At present, there are approximately seven distinctly different decompression tables and numerous electronic dive computers available to the diver. All of the available tables and many of the dive computers are based on *different* decompression models.

The U. S. Navy Standard Air Decompression, No-Decompression, and Repetitive Dive tables published in the 1958 edition of the U. S. Navy Diving Manual served as the standard for recreational and scientific scuba diving for nearly three decades [6, 7, 24]. Even though they have been highly criticized in the past decade and errors have been discovered [23], they have served the diving community well.

Several excellent format *rearrangements* simplified the use of the Navy tables for repetitive scuba diving. The tables were marketed under names such as PADI Tables, NAUI Tables, Nu-Way Tables, Dacor Tables and so on, however, they were all just rearrangements of the U.S. Navy tables. In those early years it was considered unacceptable to deviate from the exact procedures prescribed in the Navy manual for using the tables. There was no allowance for table interpolation. Many scuba divers felt *limited* by the fact that a dive schedule had to be based on the maximum depth attained during the dive, even if the diver only stayed at that depth for a few minutes. If a diver spent only three minutes at 100 feet, the no-decompression time for that dive was 25 minutes.

In the mid-70s a technique of *stepping-the-tables*, similar to one that had previously been used in oil field diving, emerged in the recreational diving community. Using this new technique a scuba diver could dive to a maximum depth of 100 feet at the beginning of a dive and progressively move to shallower depths without exceeding a no-decompression limit. The no-decompression time for a 100 foot maximum depth dive could now be extended to 60 or more minutes. Although this technique never received an official endorsement by the Navy or training agencies, it was used for thousands of scuba dives each year, especially in the Caribbean. The recreational scuba diver is by nature a multilevel diver.

Meanwhile, there appeared to be increasing controversy as to the safety of the U. S. Navy tables for a sport diving population. In 1976, Dr. Spencer published the results of his work on ultrasonically detected bubbles in the blood following U. S. Navy no-decompression dive exposures and proposed new, more conservative limits [22]. In 1981, Karl Huggins of the University of Michigan developed a complete set of no-decompression repetitive dive tables based on Spencer's values [9]. Other authorities also endorsed a more conservative approach to no-decompression diving and several new no-decompression limits appeared in recreational diving literature. Sport divers and instructors now had to decide what no-decompression limit to use.

Although electronic dive computers had been available for many years, it was not until the early 1980s that two electronic decompression microprocessors successfully entered the recreational and scientific diving market at an affordable price. Each of these computers was based on a different *decompression model*. In a review of one of these devices, the EDGE, Dr. Bassett (Skin Diver Magazine, July 1983) wrote "an innovation to sport divers equal to the original introduction of scuba." Since then other electronic devices based on still other decompression models have been released.

Not every diver will be able to afford an electronic dive computer. Consequently, today the majority of the diving community must still rely on a table for determining proper and safe dive schedules. In the United States, most instructors begin to be teaching a conservative approach to use of the U. S. Navy tables in the 1980s. Some groups have adopted the Huggins tables. A few use the British or Royal Naval tables.

In 1983 Florida dentist Ray Rogers proposed a new dive table model based, in part, on the earlier work of Spencer. Diving Science and Technology Corporation, a corporate affiliate of the Professional Association of Diving Instructors (PADI), funded a project to finalize and test tables based on this new model [1, 2, 16, 17, 19, 20]. The Rogers Tables were tested by the Institute of Applied Physiology and Medicine in Seattle under the direction of Michael Powell, PhD [15]. The test population was selected to include typical recreational divers based on sex, age, and physical condition and all testing included Doppler monitoring.

In the mid-1980s the PADI Recreational Dive Planner, based on Rogers' work, was released to the general public. These tables are designed solely for *no-decompression diving* [19]. This table provides the diver with a more conservation initial dive no decompression limit (compared to the US Navy tables). However, the diver will soon discover that these tables allows must shorter surface intervals and longer repetitive dive times than the US Navy tables. This results from the fact that Rogers uses a 60 minute half-time compartment for computing surface interval credit and residual nitrogen as compared to the 120 minute compartment used by the US Navy.

The Recreational Dive Planner is available in two formats — a Table and The Wheel. The Table format is identical to PADI's prior US Navy rearranged table format however it has 26 pressure (repetitive) groups rather than 14. The diver must still select the *exact or next higher* time and depth figure. The Wheel format allows for dive time selection to one minute intervals and has five foot depth increments to a depth of 100 feet (compared to 10 foot increments on most other tables). The Wheel may also be used to make multilevel dive calculations.

In 1985 the Canadian Defense and Civil Institute of Environmental Medicine's (DCIEM) released new air diving tables. These tables resulted from a continuous 15 year evolution of the Kidd-Stubbs decompression model. The tables are simple, easy to use, included correction factors for diving at altitude, and appeared to be more conservative than the U. S. Navy tables. From technical reports, it was evident that the tables had been calculated on a relatively conservative decompression model *and* subjected to considerable human subject testing before release. These tables are used in Canada today, however, they have not been adopted by any of the United States training agencies.

Today, there are basically two air dive tables used by the United States recreational and scientific diving communities — the US Navy and the PADI Recreational Dive Planner. Currently, the National Association of Underwater Instructors (NAUI) has designated that their instructors will teach a *conservative use* of the US Navy dive tables. NAUI has published a rearrangement of the Navy tables and redefined dive time and repetitive dive. The Professional Association of Diving Instructors (PADI) requires that all students be trained in the use of the Recreational Dive Planner.

The YMCA and Scuba Schools International (SSI) apparently remain with the US Navy tables. SSI apparently endorses the Jeppesen arrangement of the US Navy dive tables with conservative no-decompression limits based on doppler research. The Jeppesen/US Navy dive table was used in University of Michigan training programs until June 1990. At that time the University instructors elected to provided instruction in the use of the NAUI/US Navy dive table and the PADI Recreational Dive Planner in order to compliance with the requirements of these recreational diver training agencies.

The dive table controversy continues into the 1990s! Unfortunately, the controversy may be more political than physiological. The US

Navy table have 30 years of in field use with hundreds of thousands of dives. People have experienced decompression sickness using the US Navy tables, however, the incidence is not nearly as serious as some individuals would lead you to think. *When used properly* the incidence of decompression sickness on US Navy tables is said to be less than 0.01 percent [28]. It is too soon to establish an incidence of decompression sickness for the Recreational Dive Planner. Although the initial test results were apparently excellent, the true test lies in long term use by the general diving population.

All divers must keep in mind that no decompression model, no dive table, or no dive computer can assure complete freedom from incidence of decompression sickness. There are simply too many variables. The best that we can hope for is to keep the incidence to an absolute minimum through proper training, understanding basic diving physiology, and common sense diving procedures.

At the present time we are all a bit confused by the number of alternatives in dive tables and computers available to the beginning diver. Today it is possible for a group of 10 divers to enter the water and for each to be using a dive table or computer that is based on a different mathematical model. In this training program you will be introduced to the basic physiological principles of nitrogen absorption and elimination, instructed in the use of both US Navy and Recreational Dive Planner tables, provided with an overview of diver computers, and provided with insight into the proper application of dive tables and computers in routine diving activities.

DECOMPRESSION: WHY AND HOW!

When air is breathed under pressure the inert component, nitrogen, diffuses into the various tissues of the body. Nitrogen uptake by the body continues at various rates as long as the partial pressure of the nitrogen in the inspired gas is higher than the partial pressure of the nitrogen already absorbed in the tissues. The amount of nitrogen absorbed is primarily dependent upon the partial pressure of the inspired nitrogen (depth) and the duration of exposure to pressure (time).

When the diver begins to ascend, the process is reversed as the partial pressure of nitrogen in the tissue exceeds that in the circulatory and respiratory systems. The pressure gradient between the tissues and the blood and lungs must be carefully controlled in order to prevent too rapid of a diffusion of nitrogen. If pressure changes take place too rapidly and a sufficiently steep gradient develops, nitrogen bubbles can form in the blood and tissues. These bubbles ultimately can lead to the development of decompression sickness.

To minimize the possibility of decompression sickness, special tables and procedures have been established. These tables, based on the amount of nitrogen absorbed by various theoretical compartments at various pressures for given time periods, are designed to maintain a pressure gradient that, *in theory*, prevents harmful bubble formation. They allow for natural elimination of nitrogen through normal circulation of dissolved gases in the blood stream and normal gas diffusion in the lungs.

Today, no-decompression is the buzz word of recreational diving. Divers are encouraged to never exceed the no-decompression limits of dive tables. One popular dive table is based solely on no-decompression dive limits. In reality, there is no such thing as a no-decompression dive. Basically, you decompress from any exposure to pressure when you ascend — even in a swimming pool. The British use the term *no-stop dive*. This is probably a more appropriate term.

There are three primary methods of decompression or pressure reduction following exposure to depth. *Linear decompression* is probably the oldest form of decompression. In linear decompression the rate of pressure change is constant. Linear decompression is used today for dives which do not exceed the no-decompression depth-time limits. In this case the diver is permitted to ascend directly from depth to surface pressure at a constant rate not to exceed 60 fpm.

Modified linear decompression is sometimes used for ascent from a saturation dive. Saturation dives involve extremely long exposure to pressures, generally exceeding 24 hours. The body tissues become fully saturated with inert gas at a pressure equivalent to the depth of exposure. One approach to decompression of saturated divers is a very slow constant rate of pressure reduction. In reality, such a decompression is generally modified to involve up to three different rates through three depth ranges.

Curvilinear decompression is one in which the rate of pressure change is constantly decreasing. Essentially, a curvilinear decompression attempts to follow the model's nitrogen elimination curve. Theoretically, it provides a fixed, optimum gradient between tissue inert gas tension and alveolar inert gas partial pressure. Curvilinear decompression is the optimal technique that can be executed when using some dive computer.

In simple terms, the dive computer is designed to simulate nitrogen absorption and elimination during exposure based on a mathematical model and provides the diver with decompression information based on this model. Using the curvilinear decompression technique the diver may ascend directly to the ceiling, or safe ascent depth, indicated by the computer. This establishes an optimal gradient for nitrogen elimination. The diver continues to decompress (ascend) by keeping the actual depth equal to the ever-decreasing ceiling depth. Although this technique produces the optimal decompression profile, it does maintain the diver at the limits of model throughout decompression. Consequently, the diver experiences the highest level of decompression stress allowed by the model.

Stage decompression is the most widely used method of decompression from a dive where linear ascent directly to the surface (a no-decompression or no-stop dive) cannot be accomplished due to the amount of exposure. Stage decompression involves ascending, at a fixed rate, from the maximum depth of the dive to a decompression *stop* at some shallower depth. After a given period of time at the stop depth, the diver ascends to the next decompression stop. This process is repeated until the diver reaches the surface. In air diving, the decompression stops are usually at 10 fsw (3msw) depth intervals. Stage decompression represents an attempt to follow the body's nitrogen elimination curve in a stepwise fashion. Stage decompression ascent profiles are relatively easy to maintain in both the water and chamber as compared to linear and curvilinear profiles.

Recreational and scientific scuba divers are encouraged to remain within no-decompression (no-stop) limits of dive tables and computers. Dive exposure which prohibit direct ascent to the surface are of much higher risk to the diver.

UNDERSTANDING AND USING DIVE TABLES

Dive tables are really quite simple. The diver simply reads the no-decompression time limit or the decompression stop requirements for a given depth. If the diver is making only one dive within a specified time period (.i.e. 12-hours for the US Navy tables, 24-hours for the NAUI tables and 6-hours for the PADI Dive Planner) the procedure is straight forward and uncomplicated. The diver must not exceed prescribed *rates-of-ascent* and is encouraged to make an *ascent control stop* for all dives.

Procedures for using *three* dive tables will be included in this discussion — the US Navy dive tables, the NAUI dive tables, and the PADI Recreational Dive Planner. The procedures for use of the US Navy Dive table are a conservative modification of standard US Navy procedures (as given in the *US Navy Diving Manual*) based on new findings and trends in recreational and scientific diving. The NAUI dive tables is a conservative modification of the US Nay dive tables. *Since the procedures for the use of the Recreational Dive Planner have been published and specifically designated by the Professional Association of Diving Instructors, the procedures designated with that table should be used and are also addressed in this publication.*

Specific procedures and values endorsed by the University of Michigan instructors for using US Navy dive tables are presented in bold type.

No-Decompression Time Limits: Unfortunately, all of the dive tables commonly used by recreational and scientific divers have different no-decompression (no-stop) limits. For some this becomes quite confusing. The following values are the no-decompression limits for (1) Jeppesen modified limits for conservative use of the US Navy dive tables (MN), (2) NAUI modified limits for US Navy Tables (NAU), (3) the PADI Recreational Dive Planner (RDP), (4) the Canadian DCEIM Sport Diver Table (DCEIM), and (5) the original 1958 US Navy dive tables (USN) (depth in feet, time in minutes):

DEPTH	MN	NAU	RDP	DECIM	USN
30	205	-	-	360	-
35	160	-	205	-	310
40	130	130	140	175	200
50	70	80	80	75	100
60	50	55	55	50	60
70	40	45	40	35	50
80	30	35	30	25	40
90	25	25	25	20	30
100	20	22	20	15	25
110	15	15	16	12	20
120	10	12	13	10	15
130	5	8	10	8	10

These are the most common dive tables and limits that you will encounter in United States recreational and scientific diving at this time. The limits designated in under column "NAU" are to be used with the NAUI arrangement of the US Navy dive tables and the limits under column "RDP" are to be used with the Recreation Dive Planner. Most authorities recommend that divers never exceed prescribed limits and whenever possible avoid diving to the limits of the tables.

Avoid Diving to the Limits of the Tables!

Depth: When reading dive tables depth is the *maximum depth attained during the dive* and is expressed in feet or meters of sea water. Most dive manuals and tables published in the United States use feet of sea water (FSW). Since most tables are presented in 5 or 10 foot depth intervals, the diver must use the *exact or next greater depth* to determine the appropriate dive schedule (e.g., if 56 feet is the measured depth, use the 60 foot dive table depth). When using the NAUI dive table consider any dive depth shallower than 40 feet as a 40 foot dive.

Dive Table Depth is the Maximum Depth Attained During the Dive

For cold and/or arduous dives you are encouraged to use a more conservative dive schedule. This is easily accomplished by *adding 10 feet to the measured dive depth* for purposes of determining table entry depth (e.g., if 56 feet is the measured depth, use the 70 foot dive table depth).

Cold and/or Arduous Dive: Add 10 Feet

NAUI has elected to use the next greater bottom time to address cold or strenuous dives. For example, for example if you wish to remain within the no-decompression dive time limit for a depth of 60 feet and you are cold, limit the dive to 50 minutes or less. In order to determine the letter group at the end of the dive read the letter for the next greater bottom time (i.e., use 55 minutes).

Time: The U.S. Navy and PADI (Recreational Dive Planner) define bottom time as the total elapsed time (in minutes) from when the diver leaves the surface in descent to the time that the diver *begins* ascent. NAUI defines dive (bottom) time as the total time spent underwater exclusive of the precautionary decompression stop time. Many scientific and recreational scuba divers now use a more conservative definition of bottom or dive time. They define *bottom time as total dive time or time spent underwater* on any given dive. This is more practical in that most divers now use dive timers or computers that are automatically activated and deactivated by pressure (water depth) at the beginning and end of the dive. Since it is not practical to publish a dive table with minute-by-minute schedules, the diver must use *the exact or next greater time* to determine the appropriate dive schedule (e.g., a 42 minute dive to 60 feet would be read as a 50 minute time on the US Navy dive table).

In the UM training programs and operational diving we use the more conservative definition of bottom time — *basically surface to* *surface* for no-decompression dives. However, time spent at an *ascent control stop* (or precautionary decompression stop), to be discussed later, is considered *neutral time* and need not be included as bottom time for purposes of reading tables.

Bottom Time:
Total Time Underwater
Exclusive of Time Spent at the
Precautionary Decompression Stop

Rate of Ascent. The rate at which the diver returns to the surface is specified for specific tables. Both the US Navy and PADI Recreational Dive Planner specify 60 feet per minute. NAUI specifies the rate of ascent as "not to exceed 60 feet per minute." Rate of ascent has been a controversial topic over the last few years. Some authorities suggest that the dive should ascend at a slower rate such as 30 to 40 feet per minute. Others suggest that ascent rate is not a major factor from a standpoint of bubble formation. US Navy tables used prior to 1958 specified a 25 foot per minute ascent rate for deep-sea or hard-hat divers. As compressed air scuba diving became more popular with special warfare groups, a faster ascent rate was requested. The 60 feet per minute ascent rate was a compromise between hard hat divers and scuba divers.

Presently, most authorities have agreed that the *rate of ascent should not exceed 60 feet per minute* and that the diver may ascend at a slower rate if so desired. Physiologically, it appears that an ascent control stop can be more important than slowed rates of ascent.

Rate of Ascent:
Not to Exceed 60 Feet/Minute

Ascent Control Stop. Researchers have shown that tiny bubbles (venous gas emboli or VGE) form in the divers blood stream during ascent from many, if not most, dives. Although a diver may often develop VGE during ascent, symptoms of decompression sickness may or may not pursue. These tiny bubbles indicate a degree of decompression stress on the diver. Although the VGE-decompresson sickness relationship is still contested, research is revealing a probable correlation between high levels of VGE and decompression sickness. Revised and reduced no-decompression limits initially resulted from this discovery.

Later research suggested that *stopping for a few minutes during ascent* was as likely to reduce or preclude detectable VGE formation than reducing the no-decompression limits [14]. The next subject of controversy was, how long and at what depth? Participants in a workshop on diver ascent sponsored by the American Academy of Underwater Sciences (October 1989) concluded that divers should stop in a depth zone of 10 to 30 feet for 3 to 5 minutes during ascent from all dives. This procedure was taught at the University of Michigan for several years and is still used by many University divers. However, the procedures currently recommended in the instructional program have been adjusted to reflect those prescribed by NAUI and PADI.

From a practical standpoint, allowing the diver to stop in a depth zone is far more realistic than establishing a fixed depth. In typical Caribbean diving, a diver can relax and explore the surroundings and not worry as much about precise depth or depth maintenance. Furthermore, if there are rough (high wave) surface conditions, the diver can more comfortably stop at 25 to 30 feet than 10 to 15 feet. The time flexibility can relate to the nature of the dive, the number of dives, or environment conditions. For example, some divers will stop for 3 minutes during ascent from the first dive of the day and 5 minutes for subsequent dives.

Ascent Control Stop:
3 Minutes at 15 Feet!
(Neutral Time)

For all practical purposes, this stop time may be considered as *neutral time*. In other words, it need not be included as bottom time for purposes of reading dive tables. However, some conservative divers do included it in their surface-to-surface time or bottom time. In our opinion, if the stop time exceeds 5 minutes, the additional time should be considered as bottom time.

At present, divers using the PADI Recreational Dive Planner are required to make a *safety stop* for 3 minutes at 15 feet if the diver comes within 3 pressure groups (defined later) of a no-decompression time limit, and for any dive to a depth of 100 feet or greater. Divers using the NAUI dive tables are encouraged to make a 3 minutes *precautionary decompression stop* at a depth of 15 feet during ascent for any no-decompression dive.

Repetitive Dives

Most scuba divers make more than one dive in any given diving day. Some will make as many as 5 to 7 dives. However, most authorities now agree that three dives per day is a more reasonable limit.

Number of Dives:
Limit to 3 Per Day

Repetitive Dives: A repetitive dive refers to any dive conducted with a specified time of a previous dive. The U.S. Navy repetitive dive tables define *a repetitive dive as any dive conducted within 12-hours of a previous dive.* On the other hand, the Recreational Dive Planner (PADI) defines a repetitive dive as any dive conducted within *6-hours* of a previous dive. To the contrary, NAUI considers any dive conducted within *24-hours* of a previous to be a repetitive dive. The Canadian and British dive tables require repetitive dive calculation procedures up to 18 and 16 hours, respectively, depending on the diver's nitrogen retention level value at the completion of the previous dive. Post-dive inert gas retention and elimination will be discussed in another section of this manual.

In order to be designated as a repetitive dive, the US Navy specifies that a surface interval of at least 10 minutes must elapse. Let's assume that a diver, working at a depth of 50 feet, accidentally releases a buoyant object an it floats to the surface. The diver ascends, retrieves the object within 5 minutes, and wishes to return to the work site at 50 feet. Returning to 50 feet is not considered to be a repetitive dive; *it is a continuation of the current dive!* Why? The dive spent less than 10 minutes on the surface.

By strict US Navy procedure, the ascent time and the surface time need not be included as dive or bottom time. Strictly speaking, the diver could add the bottom times of the two segments of the diver to determine the actual total bottom time for the dive. However, from a practical standpoint, most divers simply include both the ascent and surface time in their bottom times and treat the entire event as a single, continuous dive.

The times (12 hours and 6 hours) are determined by the theoretical half-time compartment on which the Surface Interval Credit Tables calculations are based. For example, the US Navy designates the 120-minute half-time compartment as the controlling compartment. Consequently, in theory, a 12 hour time period is required to rid the body of accumulated nitrogen. In reality, this may or may not be so. It appears that NAUI arbitrarily elected to use 24-hours in a more conservative adaptation of the US Navy dive tables.

On the other hand, the mathematical model used to develop the Recreational Dive Planner assumes that all no-decompression dives can be controlled by a compartment with a faster than 60 minute half-time. Consequently, in theory, a 6 hour time period is required to rid the body of accumulated nitrogen. In reality, this may or may not be true. You will find that the Recreational Dive Planner will give shorter surface intervals and longer repetitive dive times for the same depth-time situations than the US Navy tables. Please do not let this confuse you. Keep in mind that each of these tables was based on a different mathematical model.

In order to compute repetitive dive times, we must consider the amount of nitrogen still retained by the body from previous dives and the surface interval between dives. Using this information, the diver will compute the maximum allowable no-decompression time for a repetitive dive.

A day of repetitive diving should be planned so that the deepest dive is performed first and successive dives are progressively shallower. The places less decompression stress on the diver and allows for longer no-decompression dives throughout the day.

Make the Deepest Dive First and Successive Dives Progressively Shallower!

Repetitive Group Designation: Based on depth and time of a dive, a letter is used to designate a theoretical level of nitrogen in the body immediately following the dive. This is a repetitive group or pressure group. For example, if a diver surfaces from a 40 minute dive to 60 feet, the US Navy repetitive group is "G". The higher the letter, the higher the level of nitrogen retained in the body.

Letters are used for most dive tables. These letters are not interchangeable. Do not mix tables and table values! Your companions pressure group "G" on the Recreational Dive Planner is a totally different value that your repetitive or letter group "G" on the US Navy dive tables.

Surface Interval: This is the time between repetitive dives. Officially, the surface interval begins as soon as the diver surfaces and ends when the diver begins the descent of the following or repetitive dive. From a practical standpoint most divers will simply compute repetitive dives based on an approximate and conservative surface interval. Let's assume that a group of divers return to their boat between 10:30 and 11 AM (the last diver is on board a few minutes before 11). Practically speaking, the surface interval can begin at 11 AM. The group leader informs the divers that they will be leaving the dock for the afternoon dive at 2 PM and be on site and ready to dive no later than 2:15 PM. In this situation, more conservative divers will simply use a three hour surface interval to compute the repetitive dive even though the surface interval may exceed 3 hours by 15 to 20 minutes. In most cases this would be considered as conservative diving!

Modern trends in dive planning appear to be toward more preciseness in timing and computation. For example, the Recreational Dive Planner has 26 pressure or repetitive groups compared to 14 of the US Navy tables. Consequently, the diver can use very precise surface interval, almost to the minute in some cases, to optimize repetitive dive time. Optimizing time also removes some of the safety buffer associated with more conservative use of tables. Squeezing every last minute out of a table is, in my opinion, eventually going to get some divers in trouble.

Some instructors and researchers have also expressed concern with regard to short surface intervals and the practice of bounce diving (i.e., repetitive deep, short duration dives with limited surface intervals). Since this is an area of concern that must still be explored by researchers, it is our recommendation that the minimum surface interval between dives be established at 1 hour until more information is available.

Minimum Surface Interval: 1 Hour

The PADI Recreational Dive Planner also has special rules for multiple dives. If you are planning three or more dives per day, beginning with your first dive, if the ending pressure group is W or X, the minimum surface interval between subsequent dives is 1 hour. If the ending pressure group is Y or Z, the minimum surface interval between all subsequent dives is 3 hours.

PADI Recreational Dive Planner: Observe Special Rules for Multiple Dives!

Surface Interval Credit and New Repetitive Group: During ascent and on the surface following a dive, you are *off-gassing*. In other words, your body continues to release excess nitrogen to the atmosphere with each breath until you return to pressure (dive again) or reach equilibrium with the atmosphere. Consequently, your repetitive group letter decreases as the length of surface interval increases. If your were a "G-diver" when you surfaced at 11 AM, you will be a "C-diver" for your 2 PM dive (NAUI/US Navy tables).

Residual Nitrogen: Practically speaking, this is the amount of nitrogen that remains in you body following a specific surface interval. This excess nitrogen must be accounted for when computing a repetitive dive. *Dive tables specify this residual or remaining nitrogen in terms of minutes of time that must be added to the repetitive dive in order to adjust for the nitrogen remaining from a prior dive(s).* The value, in minutes, will vary for the same repetitive group depending on the depth of the repetitive dive. For example, if our "C-diver" using the NAUI/US Navy tables plans to dive to a depth of 60 feet on the afternoon dive, the residual nitrogen time is 17 minutes. In other words, the diver begins the dive with an assumption that 17 minutes of bottom time have already elapsed, physiologically speaking. If the afternoon diver was limited to 40 feet, the residual nitrogen time would be 25 minutes.

Repetitive Dive No-Decompression Limit: The most frequent computation in scuba diving is determination of repetitive dive no-decompression time. This is quite simple. The no-decompression time for a specific depth is designated on the dive table. Keep in mind that this limit is for the initial dive only. *To determine the no-decompression limit for a repetitive dive, you must subtract the residual nitrogen time from the original no-decompression time for the planned depth of the repetitive dive.*

Let's assume that our "C-diver" (above) actually wishes to return to 60 feet on the afternoon dive. The revised no-decompression limit for 60 feet is 55 minutes. Subtract 17 minutes of residual nitrogen from 55 minutes and you have the maximum no-decompression dive time for the repetitive dive — 38 minutes. Several practice repetitive dive problems are included in the Appendices of this Section.

Drawing the Dive Profile. One of the best ways to prevent mistakes and avoid confusion in repetitive dive computation is to graphically represent the series of dives as a drawing — a dive profile. Enter all information on the dive profile. Ideally, both members of the buddy team should draw dive profiles and compare them when finalizing the dive plan. Dive profiles are included in the appendices of this section.

Depth Limits: Scuba diving depth limits have been discussed previously. For our purposes, any dive in excess of 60 feet shall be considered as a deep dive. This simply means that the diver shall take an extra degree of care in planning the dive and computing dive schedules.

Deep Dive:
Depth in Excess of 60 Feet

The absolute limit for recreational divers has been placed at a depth of 130 feet and an increasing number of instructors and organizations now endorse a 100 foot depth limit. For our purposes, recreational scuba diving shall be limited to depths of 100 feet or less. Even if the diver exceeds 100 feet on the initial dive of the day, many authorities now encourage divers to not exceed 100 feet on repetitive dives.

Recreational Dive Depth Limit:
100 Feet

Multilevel Dives: The scuba diver is a multilevel diver. A scuba diver seldom goes to one specific depth and remains there for the duration of the dive. Various mechanism *stepping-the-tables* (i.e., interpolating) have been used by commercial and recreational divers over the years. Many authorities discourage this procedure because, in some cases, dive times indicated safe by table-stepping are shown to exceed the safe times limits of the table model.

Currently, the *Wheel* version of the Recreational Dive Planner is used to compute planned recreational multilevel dives. In theory, the diver computes the various stages (levels or steps) of the dive and records this information on a slate prior to entering the water. The diver must now accurately monitor time and depth at each level to assure safety. In reality, divers do a poor job of monitoring depth and time even at just one level. The task of monitoring time and maintaining specific depth limits for two or three levels can become complicated and is subject to increased error.

Considering the complexity and potential for error, it is our opinion that multilevel dives be made only when using an electronic dive computer that continuously monitors the diver's theoretical nitrogen status.

Multilevel Dive Profiles: Only with a Dive Computer

Exceeding No-Decompression Limits: Both recreational and scientific scuba divers are encouraged to remain within the no-decompression limits (no-stop limits) of dive tables. The PADI Recreational Dive Planner is strictly a no-decompression and exceeding a no-decompression limit is considered an emergency situation. For example, if you exceed the no-decompression limit by no more than 5 minutes, an 8-minute stop is mandatory at a depth of 15 feet and upon surfacing you must remain out of the water for at least 6 hours prior to making another dive. If you exceed the no-decompression limit by more than 5 minutes, a 15 foot decompression stop of no less than 15-minute (air permitting) is recommended and the diver must remain out of the water for 24 hours prior to making another dive.

In NAUI's adaptation of the US Navy Dive tables decompression time requirements are included for selected dive times that exceed the no-decompression time limits. The decompression depth is designated as 15 feet.

The U.S. Navy Standard Air Decompression Table gives stage decompression stops at 10 foot intervals for dive times that exceed the U.S. Navy's no-decompression limits. For example, this table requires a stop of 14 minutes at 10 feet for a dive to 120 feet for 30 minutes. These tables have been used for more than 30 years. The US Navy does acknowledge an increased incidence of decompression sickness associated with decompression dives and discourages decompression dives when using scuba.

The recreational and scientific diving community has also discouraged dives that require decompression. Furthermore, although various "experts" have dealt with no-decompression limits, rates of ascent, and safety stops, little information is available on air decompression diving. At present, we can only encourage scuba divers to avoid dives requiring decompression. In the event that decompression is unavoidable, a conservative approach is suggested. For example, some divers use a dive table depth that is 10 to 20 feet deeper than the actual dive depth to determine decompression. Furthermore, if at all possible, avoid making repetitive dives following a decompression dive.

Dives Requiring Decompression: Not Recommended!

Multi-Day Diving: Most scientific and vacationing recreational divers tend to make one to two week long diving trips. Since most divers are paying ā high price for their diving holiday, they wish to make as many dives as possible during this time period. Physiologist and diving authorities are now expressing increasing concern about divers who make several dives daily for several consecutive days. There is concern that slower level tissues will become progressively saturated and ultimately invalidate the decompression models. *Consequently, some authorities recommend that divers allow a 18 to 24 hour period of non-diving activity after every 3 consecutive days of repetitive diving.*

Reading Tables: The procedures for reading decompression tables are fairly straight forward and are included included in the appendices of the Section. In addition, they will be addressed in detail in lecture sessions.

HOW SAFE ARE DIVE TABLES?

Several publications and many recreational scuba diving instructors cite that a high incidence of decompression sickness can be expected even when the diver is using the U.S. Navy dive tables. A figure of 5% incidence is most frequently stated and figures as high as 10% are not uncommon. Such figures are without foundation. Some claimed that the US Navy accepted a 5% incidence of bends when initially developing and testing the tables. This is absolutely untrue. In fact, if decompression sickness did develop during testing, the schedule was adjusted and retested till the incidence was 0.00% [6, 7, 13].

Until 1970 there was simply a lack of reliable statistical data on bends incidence in air diving. The unfortunate combination of unfounded incidence percentages and lack of statistical data led to distrust, fear and in some cases disregard of the U.S. Navy tables. Arbitrary safety factors were promoted. Some individuals used this *uncertainty* to promote the use of dive computers and other tables.

In 1970 the U.S. Navy adopted a reporting system for both the number of decompression sickness cases and the number of dives. For the period of July 1, 1970 to June 30, 1971, the U.S. Navy documented 25 cases of decompression sickness out of 30,039 dives. Air dive exposures accounted for 26,035 dives and only 12 decompression accidents were noted in air diving, or an overall 0.046% incidence. The incidence for open-circuit scuba diving was slightly less. Expressed in terms of a risk factor, this is one case per 2,857 exposures for all dives [3].

In the 24-month period from January 1972 through December 1973, U.S. Navy divers recorded 127,103 dives or 97,242 person hours under pressure. Only 35 cases of decompression sickness were reported during this study period giving an incidence of about 0.03%. It is significant to note that only 12% of all dives were in the depth range of 100 to 200 fsw; however, dives in this depth range accounted for 57% of the cases of decompression sickness. Only about 7% of the annual dives involved decompression, but gave an incidence of 0.41% decompression sickness [4].

These early figures reflect an excellent record for the U.S. Navy divers and the U.S. Navy tables and are included for historical perspective. As data reporting and analysis of statistical data improved, the incidence of decompression sickness appears to be even lower for Navy divers. More recent reports indicate that decompression sickness does occur, even on apparently safe schedules. However, it should be noted that statistics for over 240,000 dives conducted by Navy divers indicated an average decompression risk of less than 0.01 percent [12, 28].

If the US Navy tables are apparently so safe, why is there such a concern today? Why have the no-decompression limits been modified? Why have so many new tables been developed? Why were the Navy tables so severely chastised? *First of all, many divers simply refuse to accept blame for their own mistakes. Divers are careless. Many simply fail to monitor depth and time correctly.* Some are under the impression that tables and rules do not apply to them. Others simply cannot read tables or compute repetitive dive schedules. For the experienced divers and instructors that I have offended with the above statements, I *do not* apologize! You know it is true as well as I do.

Furthermore, modern trends in diver education, in my opinion, preclude adequate training in the use of dive tables. In today's short courses, trainees simply do not have time to learn and *practice* use of dive tables. What many trainees learn may be soon forgotten. I feel that many Caribbean dive guides would support this statement. But of even greater concern, in many cases new divers are not being provided with sufficient information to understand and appreciate the gravity of the subject.

Second, our great American legal system is unable, in many cases, to accept the fact that ultimately individuals must take responsibility for their own actions. Even with the excellent safety record of the US Navy tables and the acknowledged certainty that it is impossible to develop a mathematical model of the human body that will enable development of an absolutely bend-free table, injured divers have still sued everyone in sight. Consequently, some, if not many, changes have been driven by "cover your hind end" factors rather than physiological factors.

Third, in 1976 Spencer published the fact that little bubbles are rushing around in the circulatory system following many asymptomatic dive exposures [22]. The Doppler technology was not available 20 years prior when the Navy tables were developed. This fostered an immediate response of concern in the diving community. Several individuals published reduced no-decompression limits and even new dive tables based on these findings [9]. Later research revealed that making a stop on the way to the surface, even if the table was pushed to the maximum no-decompression limit, indicated significant reduction in bubble formation [14].

Fourth, recreatinonal dives often push tables and dive computers to their absolute limits. On the other hand Navy divers by nature are more conservation. They either back off from the limit or "jump schedules" (i.e., use deeper depth and longer times that actually encountered during the dive to read tables). If enough people go to the edge enough times, some one is going to fall off. Divers who push the table limits run a higher risk of decompression sickness.

Fifth, recreational divers may increase their susceptibility to decompression sickness due to physical compromises. Basically, they invalidate the table models. Social habits alone compromise many divers. We live in an alcohol dominated society. Far too often divers are physiological compromised by the effects of alcohol and subsequent dehydration when they enter the water. This can significantly alter the nitrogen absorption-elimination mechanism(s) of the body.

Finally, one cannot escape the inter-agency politics and potential for economic gain associated with today's dive tables. There is both community status and economic advantage in producing and successfully marketing the "so-called" best dive table. We must also contend with the diving community's "one-ups personship" game and ego factors among it's leaders. New waterproof dive tables are marketed at $8 to $10 each. Special versions of the dive tables sell for $13 to $35. In theory, when a new dive table is issued hundreds of thousands of divers are encouraged to purchase new ones.

The fact remains that civilian divers have experienced decompression sickness while *apparently* following the tables exactly. The exact number and incidence percentage is not known since there is currently no effective data collecting system that identifies both the actual number of decompression sickness cases *and* the actual number of dives for civilian divers. I suspect that the number of cases is relatively small, but probably higher than that of the U.S. Navy. Currently, it appears that as many as 400 to 500 U.S. recreational divers experience decompression sickness annually. This includes those using all dive tables and computers, not just the U.S. Navy tables [29, 30].

There are a number of factors to consider. First, is it virtually impossible to develop a *practical*, totally bends-free table to fit every individual and situation. The times and limitations would be prohibitive. Nitrogen absorption and elimination in the human body are dependent upon a number of variables. Tables have been developed to best protect the normal, healthy adult diver. Physiological deviations associated with poor physical condition, aging, and obesity are sufficient to precipitate bends under the same diving conditions that would be safe for a normal, healthy young adult.

Second, the level of physical exertion and the thermal status of the diver alter nitrogen absorption-elimination. Persons who have worked hard and/or chilled significantly on a dive are more susceptible to decompression sickness.

Third, daily diver condition is important. A higher incidence of decompression can be expected in individuals who are suffering from minor illness (colds, diarrhea, etc.), lack of sleep, alcohol intoxication (and hangovers), alcohol or drug consumption prior to diving, and the like.

Fourth, some table schedules show a greater tendency to produce trouble than others. For example, the no-decompression limit of 100 minutes for 50 fsw is probably questionable. Other possibly questionable schedules, beyond the range of recreational divers, include 140 fsw/30 min; 140 fsw/40 min; 150 fsw/30 min; and 170 fsw/30 min [10].

Fifth, many factors exist in the civilian recreational diving community that are less likely to confront the Navy diver. For example, recreational divers are not bound by established rules and rigid supervision. Deep air diving that would not be permitted under Navy regulations, is common place in civilian diving. Furthermore, Navy divers are required to have a medical officer and hyperbaric chamber at the dive site for dives beyond a depth of 190 feet.

Many divers take a *haphazard* approach toward monitoring their depth gauge and dive timer. Consequently, it is not possible to select the appropriate dive schedule if you do not know the precise depth and time. Furthermore, depth gauges used in recreational diving may have an accuracy deviation of up to ± 5% of full scale depending upon the gauge model and manufacturer. This means that a new gauge (250 fsw model) could have a variation of 37.5 fsw to 62.5 fsw at an actual depth of 50 fsw and 117.5 fsw to 142.5 fsw at 130 fsw. In addition, mechanical damage from use and abuse can cause even greater variation. Until the recent development of better depth gauges and mechanical- or electronic-device that automatically recorded or marked maximum depth, many divers did not really know their exact maximum depth on any given dive.

Many recreational divers take exceptional liberties with personal modification of the U.S. Navy tables. Several modification schemes for multi-depth level scuba diving have been advanced in recent years. Although these *schemes* may appear logical and apparently work, they are generally not properly conceived or tested.

Conservatively used for no-decompression dives in depths of 100 fsw or less and with accurate depth-time determination, the U.S. Navy tables should provide the civilian diving population with a very low, if not negligible incidence of decompression sickness. Conservative recommendations have been given in the preceding discussion. *However, all divers must understand and accept the fact that no dive table or computer can guarantee bends-free diving.*

The same questions are now being asked regarding the safety of the PADI recreational Dive Planner. Preliminary testing in the laboratory and open water with modern ultrasonic Doppler equipment that was not available when the US Navy tables were developed suggest that the model and table maybe valid. However, the true test lies in extensive use by the general diving public. Insufficient data exists at this time to draw any final conclusions.

FLYING AFTER DIVING

When a diver surfaces following a dive, an elevated dissolved nitrogen tension exists in the body's tissues and fluids. The dive tables are calculated to keep the nitrogen tension below the theoretical critical level at which bubble formation would result when the diver returns to the surface pressure (sea level). If the diver then immediately ascends to a higher altitude in an aircraft or drives into the mountains, the reduction in ambient pressure can result in nitrogen tensions within the body that exceed the critical level for bubble formation. Consequently, the diver who was *safe* at sea level, can develop serious decompression sickness upon ascent to altitude.

Following an exposure to pressure the diver must remain at sea level for some specific period of time before ascending to altitude in order to allow the body to equilibrate. Exactly how long appears to be a subject of considerable controversy.

The U.S. Navy Diving Manual (1973 edition, p. 6-44) stated that the diver "definitely must not fly for at least 12 hours [25]." NOAA Diving Manual (published in 1979) stated, "Before flying in an aircraft in which the atmosphere will be less than 8,000 feet (usually the case in most flights), a diver who has completed any number of dives on air, and decompressed following the U.S. Navy Standard Air Decompression Tables, should wait at sea level breathing air for the computed surface interval that allows him to be classified as a Group D diver in the U.S. Navy Repetitive Dive Table [11]."

A more recent edition of the US Navy Diving Manual (1985 edition, p. 7-22) indicates, "Flying in aircraft with cabin pressures above 2300 feet altitude may be done after a 2-hour surface interval for no-decompression air dives and 12 hours for decompression dives. If aircraft cabin pressure is below 2300 feet altitude, then flying may be done immediately after an air dive [26]." Other dive manuals and research reports state times ranging from 2 to 24 hours [8].

The PADI Recreational Dive Planner designates that the diver must wait a *minimum of 4 hours* following a single no-decompression dive with less than 1 hour of bottom time. For a single no-decompression dive with a bottom time of more than one hour or after any repetitive dive, the diver must wait a *minimum of 12 hours.* Following any dive that required emergency decompression, the diver must wait a minimum of 24 hours before flying. The instructions further state that, whenever possible, a 24 hour wait is generally recommended in most cases [19].

The general lack of agreement among various authorities tends to leave the average diver with a degree of uncertainty. When in doubt, take the more conservative approach. If for some reason the cabin pressure were to be lost during a flight, the diver flying within a short period of time following any dive would be extremely susceptible to decompression sickness.

The following recommendations were made by a group of diving physiology and medicine authorities at the Undersea and Hyperbaric Medical Society's "Flying after Diving Workshop" (24 February 1989) for no-decompression diving [21]:

a. If you have *less that 2 hours* of accumulated dive time in the last 48 hours, wait 12 hours before flying.

b. For unlimited, multiday diving or if you have *greater than 2 hours bottom time* in the last 48 hours, wait 24 hours before flying.

If you made a decompression dive, wait at least 24 to 48 hours (48 hours if possible) before flying.

Minimum Surface Interval Before Flying (No-Decompression Dive): 12 Hours

Because of the complex nature of decompression sickness and because unverifiable assumptions are involved in decompression schedules, there can never be a flying-following-diving rule that is guaranteed to prevent bends completely!

DIVES AT HIGH ALTITUDE

U.S. Navy air dive tables were computed for diving with reference to sea level. The current US Navy tables (addressed in the 1985 edition of the US Navy Diving Manual, p. 7-22) may be used for diving in fresh water at altitudes up to 2300 feet provided that the actual measured depth, not depth gauge depth is used, to determine dive schedules and that if decompression is required, a decompression line measured from the surface is used and stop depths are increased by one foot [26].

NAUI Recommends that the US Navy Dive Tables be Limited to Altitudes of Less than 1000 Feet Above Sea Level!

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The PADI Recreational Dive Planner is not Designed for Use at Altitudes Greater than 1000 Feet Above Sea Level!

For diving at higher altitudes, two modifications must be made to correct for differences in atmospheric pressure when standard sea-level tables are used. The diver must compute, or refer to a table to obtain, the theoretical depth of the dive and the theoretical depth of decompression stops for a given altitude. Both the theoretical diving depth and decompression stop depths will vary with altitude. In addition, the diver's tissue nitrogen tensions change when traveling from sea level to altitude. An adaptation period or special dive table considerations are required. Also, conventional depth gauges may give erroneous readings when used at altitude and correction factors are required.

There are various procedures and tables for computing no-decompression limits and decompression schedules for high altitude diving. However, at the present time for diving at altitudes in excess of 2300 feet (700 meters) we recommend using the Buhlmann "Decompression Tables for Dives with Air at Various Altitudes" (Buhlmann, A., Decompression-Decompression Sickness (New York: Springer-Verlag, 1984) [5].

CONCLUSIONS

At present the risk of decompression sickness can be minimized, but not totally eliminated, through the *proper use* of dive tables and computers. Unfortunately, divers must select from among many dive tables and computers. This selection is difficult and debated even among the most knowledgeable experts in the field of diving. Dive tables and computers are aggressively advertised and marketed for prestige and profit, rather than simply the safety of the diver. I am certain that no one is advocating a table or device that is knowingly unsafe. However, the consumer is simply overwhelmed at this point in time. Fortunately, responsible individuals under the leadership of the Divers Alert Network, Duke University Medical School, and the Undersea and Hyperbaric Medical Society are attempting to sort out this entire issue.

Although this is only a superficial overview, you now know more about dive tables than most instructors. Most entry level divers are sheltered from the controversies that rage throughout our diving community. In many classes dive tables are *marketed*, not taught! Instructors and organizations tend to overlook the fact that it is your body and that you have a right to know something, actually a lot, about what you can expect to happen when you go under pressure.

Hopefully, the issues of decompression will soon be sorted out. Some of the information presented above may soon be obsolete. However, this is the picture as I see it now. All divers are cautioned to remain abreast of the latest developments through continuing education courses and seminars, attending lectures, and following diving literature.

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APPENDIX A

INTRODUCTION TO THE RECREATIONAL DIVE PLANNER
(TABLE VERSION)

INTRODUCTION

Terminology and basic procedures for using the Recreational Dive Planner were discussed throughout this Chapter 4-2. The following is a step-by-step progression through the various tables of the Recreational Dive Planner.

TABLE 1

Recreational Dive Planner Table 1 is used to determine maximum no-decompression and repetitive dive group. If you are planning only one dive in a six hour period, this is the only table that you will need to use. The best way to explain a dive table is through a example.

Let's assume that you intend to dive to a maximum depth of 55 feet. Depth is given in 10-foot increments (after the 35-foot column) at the top of table one. Since 55 feet is between 50 and 60 feet, *you must use the higher depth column for planning your dive.*

The maximum no-decompression time for that dive depth is displayed in the box at the bottom of the column. In this case the maximum no-decompression dive time for 55 feet (60 foot column) is 55 minutes.

Upon completion of your dive (Dive #1) to 55 feet your timer reads 35 minutes bottom time. If you enter the 60 foot column to 35 minutes, you can determine your Pressure Group at the end of that dive by reading the letter at the left side of Table 1. In this case you are in Pressure Group N. This information is only required if you intend to dive again within 6 hours.

TABLE 2

Two hours after completing your initial dive of the day your plan to make another dive. Since your body has been off-gassing nitrogen throughout this 2 hour period, you can receive credit for this time. Table 2 — Surface Interval Credit Table — is used to determine the amount of credit. Locate Pressure Group "N" from Dive #1 on the diagonal line of letters on the left side of Table 2. Enter the "N" row horizontally to the box containing the numbers 1:31/2:18. Your surface interval is between one hour, thirty-one minutes and two hours, 18 minutes. Now, follow that column to the bottom of the table to determine your new Pressure Group — "B".

TABLE 3

Table 3 — Repetitive Dive Time Table — provides you with residual nitrogen time and maximum no decompression time allowed for your repetitive dive time. Find the letter "B" along the top of Table 3. Now, let us assume that you plan to dive to a depth of 47 feet on Dive #2. Follow the "B" column down to the 50-foot depth row of figures (depths are on the left side of Table 3). You will find two numbers. The upper number is the residual nitrogen time (in minutes) remaining from Dive #1. The bottom number is the maximum allowable actual no-decompression dive time for Dive #2 — in this case 67 minutes. This figure — 67 minutes — is the maximum no-decompression dive time for 50 feet *less* the residual nitrogen time or (80 – 13 = 67).

Let us assume that your planned bottom time for Dive #2 is only 60 minutes. *In order to determine your Pressure Group at the end of Dive #2 you must add the actual bottom time and the residual nitrogen time.* In this case 60 minutes plus 13 minutes (RNT) equals 73 minutes. This is the Total Bottom Time or Equivalent Single Dive Time (ESDT). Returning to Table 1 you find that you are now in Pressure Group "W" (since 73 is not on the table you go to the next higher number). You only need to determine this figure if you plan to make another dive within 6 hours.

PLANNING A THIRD DIVE

Let us assume that you are planning to make a third dive and you wish to return to the water as soon as possible. Keep in mind that there are *"Special Rules for Multiple Dives"* stated below Table 3. If you are planning 3 or more dives in a day, beginning with your first dive if your pressure group after any dive is "W" or "X", the minimum surface interval between all subsequent dives is 1 hour. If your ending pressure group after any dive is "Y" or "Z", the minimum surface interval between all subsequent dives is 3 hours. In this case you were in Pressure Group "W" and according to the rule your minimum surface interval must be one hour.

To plan Dive #3, enter Table 2 on row "W" and move horizontally to the box 0:57/1:02. Now find your new Pressure Group at the bottom of this column — "I".

Dive #3 is planned for a maximum depth of 40 feet. Entering the "I" column at the top of Table 3, you proceed to the 40-foot row of numbers and find that your maximum allowable actual bottom time (ABT) is 100 minutes (bottom figure).

Most authorities recommend that you make no more than 3 dives per day. Sine you have made a series of repetitive dives you must wait at least 12 hours before flying in a commercial air craft. Ideally, observe a 24 hour surface interval before flying.

DIVE PROFILE

APPENDIX B

INTRODUCTION TO THE NAUI DIVE TABLES

The National Association of Underwater Instructors has modified and rearranged the US Navy dive tables and now market them under the NAUI trademark. Unfortunately, this arrangement and the various abbreviations used differ from those use with the Recreational Dive Planner (PADI), the Jeppesen Arrangement of the US Navy Tables (SSI), and the traditional US Navy Tables.

TABLE 1: END OF DIVE LETTER GROUP

NAUI Table 1 is used to determine maximum no-decompression dive time and repetitive group. In addition, the number of minutes of decompression required in the event that you exceed the no-decompression dive time is also included. The best way to explain a dive table is through an example.

Let's assume that you intend to dive to a maximum depth of 55 feet. Depth is given in 10 foot and 3 meter increments at the left side of the table. Since 55 feet is between 50 and 60 feet, *you must use the higher depth for planning your dive.*

The maximum no-decompression time (maximum dive time or MDT) for that depth is displayed as a circled number. In this case the maximum no-decompression dive time for 55 feet (60 foot row) is 55 minutes.

> *The value used for dive time or bottom time is defined by NAUI as the ACTUAL DIVE TIME — the total time spent underwater during a dive except for precautionary decompression stop time.*

The values to the right of this circled number — 60 over 5 and 80 over 7 — represent the amount of *mandatory decompression* that would be required at a depth of 15 feet in the event that you exceeded the no-decompression time limit. The top number is the dive time and the bottom number is the required decompression time. For example, if your actual dive time (ADT) was 62 minutes you would have to make a mandatory decompression stop at 15 feet for 7 minutes.

Upon completion of your dive (Dive #1) to 55 feet your timer reads 35 minutes actual dive time (exclusive of the precautionary decompression time; in reality automatic timers would continue to function throughout the 3 minute stop at 15 feet). If you enter the 60 foot row to 35 minutes (in this case 35 minutes is between 30 and 40; you must used the higher valve), you can determine your Letter Group designation at the end of the dive by following the column in which 40 appears down and reading the letter at the bottom of the table. In this case your Letter Group is "G". This information is required only if you intend to dive again within 24 hours.

> *Please take note that NAUI defines a repetitive dive as any dive within 24 hours of a previous dive.* The Recreational Dive Planner is based on a period of 6 hours and the US Navy tables use 12 hours.

TABLE 2: SURFACE INTERVAL TIME (SIT) TABLE

Two hours after completing your initial dive of the day you plan to make another dive. Since your body has been off-gassing nitrogen throughout this 2 hour period, you can receive credit for this time. Table 2 — Surface Interval Time Table — is used to determine the amount of credit. Locate Letter Group "G" from Dive #1 at the top of Table 2 (or bottom of Table 1). Enter column "G" downward to the box containing the numbers 2:58/2:00. Your surface interval is 2 hours. Now move horizontally to the left to determine your new Letter Group — "D".

TABLE 3: REPETITIVE DIVE TIME TABLE

Table 3 — Repetitive Dive Time Table — provides you with residual nitrogen time and the maximum no-decompression time allowed for your repetitive dive. Find the letter "D" in the column at the right side of Table 3. Now, let us assume that you plan to dive to a depth of 47 feet on Dive #2. Follow the "D" row to the left to the 50 foot column (depths are indicated at the top of Table 3). You will find two numbers in a box. The upper number (light face type) is the residual nitrogen time (in minutes) remaining from Dive #1. The bottom number (bold face type) is the Adjust Maximum Dive Time (AMDT) or maximum allowable no-decompression time for Dive #2 — in this case 51 minutes. This figure — 51 minutes — is the maximum no-decompression dive time for 50 feet *less* the residual nitrogen time or (80 – 29 = 51).

Let us assume that your planned actual dive time for Dive #2 is only 40 minutes. In order to determine your Letter Group at the end of Dive #2 you must add the actual dive time (ADT) and the residual nitrogen time (RNT) to determine the total nitrogen time (TNT) of Dive #2. In this case 40 minutes (ADT) plus 29 minutes (RNT) equals 69 minutes. This is the Total Nitrogen Time (TNT). Returning to Table 1 you find that you are now in Letter Group "I". You only need this figure if you plan to make another dive within 24 hours.

PLANNING A THIRD DIVE

Let us assume that you are planning a third dive and wish to return to the water as soon as possible. Although the tables provide for surface intervals as short as 10 minutes, *the policy of NAUI is that divers observe a minimum of one hour surface interval between dives.*

You were a Letter Group "I" diver upon completion of Dive #2. To plan Dive # 3 enter Table 2 in column "I" and move down to the box 1:29/1:00. Now you can find your new Letter Group by reading the letter to the left of Table 2 — "G".

Dive #3 is planned for a maximum depth of 40 feet. Entering the "G" row into Table 3, you proceed to the 40-foot column and find that your Adjusted Maximum Dive Time (AMDT) is 57 minutes (bottom figure).

Most authorities recommend that you make no more than 3 dives per day. Since you have made a series of no-required-stop repetitive dives NAUI recommends that you wait at least 24 hours before flying in a commercial air craft.

COMPUTING MINIMUM SURFACE INTERVAL

Many diver wish to complete two successive dives with know depth and dive time requirements and remain within the no-decompression limits for both dives. Let's assume that wish to make Dive #1 to 60 feet for 50 minutes and Dive #2 to 50 feet for 60 minutes. You must determine the minimum surface interval between the two dives.

Upon completion of Dive #1 you are a Letter Group "H" diver (Table 1). In order to determine your Letter Group at the beginning of Dive #2 you must enter the 50 foot column of Table 3
to the box which indicate an adjusted maximum dive time (bottom number, bold type) of 60 minutes or greater. Reading to the right you find that you are in Letter Group "B". Now continue to the right into Table 2 until you intersect the "H" column. The minimum value in this box is 4:50 or 4 hours 50 minutes.

SPECIAL RULES AND RECOMMENDATIONS

Rate of Ascent. The maximum rate of ascent is 60 feet per minute.

Dives Shallower Than 40 Feet. Dives shallower than 40 feet are to be considered as 40 foot dives for table use.

Dive Depth. Dive depth is the maximum depth attained during the dive. Use the exact or next greater value. For example, the 50 foot schedule would be used for a dive to 42 feet.

Dive Time. Dive time is the total time spent underwater exclusive of the precautionary decompression stop time. Use the exact or next greater value. For example, for a single dive of

31 minutes at 60 feet you would use the 40 minute column to determine your Letter Group. Precautionary decompression stop time is considered to be neutral time.

Precautionary Decompression. A precautionary decompression stop of *3 minutes at 15 feet* is recommended during ascent from each dive.

Mandatory Decompression Stop Dives. Dive requiring a mandatory stop are discouraged. Decompression times are included on Table 1 for use in the event that the recommended Maximum Dive Time (no-decompression time) is accidentally exceeded.

Omitted Decompression. In the event that you exceed the Maximum Dive Time *and* omit the decompression stop you should refrain from physical activity (rest), drink plenty of fluids, breath 100% oxygen, and watch for signs or symptoms of decompression sickness. If symptoms are evident immediately acquire medical attention and hyperbaric treatment. If no symptoms are evident, do not dive for at least 24 hours.

Flying After Diving. Wait at least 24 hours following no-decompression diving. Wait at least 48 hours following a dive that required decompression or following an omitted decompression.

Cold or Strenuous Dives: Use the *next greater bottom time* for cold or strenuous dives. For example, if you wished to remain within the no-decompression dive time limit for a depth of 60 feet and you are cold, limit the dive to 50 minutes or less. In order to determine the Letter Group at the end of the dive, use the next greater bottom time — for a 50 minute dive use 55 minutes or Letter Group "I".

Diving at Altitude: NAUI recommends that the use these tables be limited to altitudes of less than 1000 feet above sea level. Special tables are required for diving at higher elevations.

PRACTICE DIVE COMPUTATIONS USING THE NAUI DIVE TABLES

1. Maximum Actual Dive Time (no-decompression) for a dive to 66 feet.

2. You have been diving to a maximum depth of 72 feet and discover that your ADT is 45 minutes. What, if any, special procedure would you take in ascending to the surface?

3. Dive #1: 72 feet/30 minutes
   Dive #2: 58 feet

   Determine the Adjusted Maximum Dive Time (AMDT) for Dive #2 following a Surface Interval Time (SIT) of 1 hour 30 minutes.

4. Dive #1: 55 feet/40 minutes
   Dive #2: 35 feet

   Determine the Adjusted Maximum Dive Time (AMDT) for Dive #2 following a Surface Interval Time (SIT) of 1 hour 30 minutes.

5. Dive #1: 95 feet/20 minutes
   Dive #2: 50 feet/40 minutes

   Determine the minimum surface interval time (SIT) require in order to complete Dive #2 without making a mandatory decompression stop.

6. Dive #1: 80 feet/35 minutes
   Surface Interval: 1 hour
   Dive #2: 50 feet for Adjusted Maximum Dive Time (no-decompression)
   Surface Interval: 1 hour
   Dive #3: 40 feet

   Determine the Adjusted Maximum Dive Time (no-decompression) allowable for Dive #3.

ANSWERS: 1. *45 min;* 2. *mandatory stop at 15 feet for 10 min;* 3. *25 min;* 4. *81 min;* 5. *46 min;* 6. *43 min*

APPENDIX C

COMPUTING MINIMUM SURFACE INTERVAL

The following instructions will address the general procedure for determining minimum surface interval using *both* the Recreational Dive Planner (RDP) and US Navy Dive Tables: NAUI Arrangement (NAUI). *You will discover that the values will vary considerably depending on the Dive Table that you use.*

PROBLEM

Dive 1: 60 feet/50 minutes
Dive 2: 50 feet/60 minutes

Compute the minimum surface interval that enables you to complete Dive 2 within the "no-decompression limit" for 50 feet.

Step 1: Draw a dive profile and enter all known information (depth and time of both dives).

Step 2: Using the No-Decompression Limits and Group Designation Table (RDP Table 1) find the pressure group (repetitive group) at the completion of Dive 1 and enter letter on your dive profile.

Answer: RDP = "U" NAUI = "H"

Step 3: Proceed to the Repetitive Dive Time Table (RDP Table 3) or Repetitive Dive Timetable (NAUI Table 3) and find 50 feet at the left side of the table (RPD) or top of the table (NAUI). Using the *RDP* follow the 50 foot row horizontally from left to right until you find the first adjusted no-decompression limit that is 60 minutes or greater (lower number in box) and follow that column up vertically to find the pressure group and enter it on your dive profile.

Answer: RDP Group "D"

Using the *NAUI Table* follow the 50 foot column down until you find the first adjusted no-decompression dive time that is 60 minutes or greater (lower number in box) and follow that role to the right margin to find the repetitive group and enter it on your dive profile.

Answer: NAUI Group "B"

Step 4: On the Surface Interval Credit Table (RDP Table 2) find pressure group "U" on the diagonal and pressure group "D" at the bottom and find the surface interval where they intersect. At this intersection you find 1:26 – 1:34.

Answer: RDP = "1 hour 26 minutes"

Using the NAUI Table follow repetitive group row "B" (Table 3) to the right to Table 2 (Surface Interval Time Table) and repetitive group "H" (bottom of Table 1) down to the box where they intersect. At this intersection you find 7:59 to 4:50.

Answer: NAUI = "4 hours 50 minutes"

CHAPTER 4-3

USES AND ABUSES OF DIVE COMPUTERS

Karl E. Huggins

INTRODUCTION

Since the introduction of dive computers (DCs) divers have been developing imaginative methods of use, not all of them very smart. This article will describe what a DC is, some of the misconceptions the general diving population have regarding them, and how they are being used. Examples of how dive are being used are presented along with recommendations adopted by the American Academy of Underwater Sciences (AAUS) for DC use in scientific diving programs.

Of major concern is the accuracy of the information passed on from instructors to students, salespersons to customers, and divers to other divers with regards to DCs. Too often in the diving community we see hearsay, biased, or inaccurate information presented on pieces of equipment as instead of factual information. DCs look as if they will be around for a while. They should not be condemned outright, nor should they be worshiped as a panacea for decompression sickness (DCS). They are only *tools*, and as such are no better or worse than the person using them.

WHAT IS A DIVE COMPUTER?

A DC is just that, a computer. It does not, as some people think, monitor the amount of nitrogen in a divers body. All it does is compute decompression status. This is done by sensing depth and time during the dive and then, by using a table or model, the decompression status is read or computed. This decompression status information is displayed to the diver, who can use it as an additional source of information in the execution of a dive.

The basic design of a DC is presented as a block diagram in Figure 1. The general components are the:

Pressure Transducer, which converts the ambient pressure surrounding the diver to a signal which is fed into the input of the A/D Converter.

A/D (Analog to Digital) Converter, which changes the pressure transducer signal to a digital "word" which can be "read" by the microprocessor.

Microprocessor, the "brain" which controls the signal flow and performs the mathematical and logical operations.

ROM (Read Only Memory), a non-volatile memory which contains the program steps which "tell" the microprocessor what to do. The ROM also contains the constants used in the program which determines the diver's decompression status.

RAM (Random Access Memory), contains the storage registers in which variable data and results are stored during computations.

Display, which presents the diver's decompression status.

Clock, which synchronizes the operational steps of the microprocessor and is used as the time input.

Power Supply, which runs the device.

Device Housing, which protects the components from the environment.

Many people believe DCs just read established dive tables. This is not true. Only one of the DCs available is table based (Suunto SME-USN). All the rest use a decompression model (algorithm) to compute the decompression status.

The algorithms used in DCs are mathematical and logical formulas with variables of depth and time, which makes them much more flexible than tables. A pure mathematical model affords an infinite number of depth/time solutions. Dive tables are finite listing of some of the solutions produced from a mathematical model.

The implementation of a decompression model in a DC is not "pure." As with tables the DC deals with depth and time increments, on a much smaller scale, based on the update interval of the computer (how often it recalculates the divers decompression status) and the resolution of the pressure transducer circuitry (the smallest change in depth it can detect). The U.S. Navy no-decompression table has only 135 depth/time combinations for depths between 0 and 140 feet of sea water (fsw). A model based computer that updates its status every 3 seconds and has a depth resolution of 0.5 fsw can distinguish 400 possible "square-wave" depth/time combinations in a one minute period over a 10 fsw depth range.

Tables also base decompression status on the assumption that the entire dive was spent at the maximum depth. Most recreational divers spend only a small fraction of their dive time at the deepest depth achieved during the dive. This means that during most of dive the diver is taking on less nitrogen than assumed by the tables. Model based DCs that update the divers status every few seconds will compensate for the changes in depth. This allows the diver to be presented with a decompression status based on the actual dive that was performed. The advantages of computing decompression status in this manner includes:

A. Profile Integration (no maximum depth – entire dive assumption).

B. Shallow portions of dive (safety stops) are taken into account.

C. Actual Depth used in Calculation (51 fsw not 60 fsw).

D. All compartments of the model are taken into account when calculating multi-level dive profiles (most table based techniques utilize the compartment representing their repetitive groups).

However, many of the advantages produce the disadvantages of DCs. If the device is pushed to its limit, the model is pushed to its limit. There are no safety factors programmed into the units except for the models which are more conservative than the U.S. Navy model. In using tables the maximum depth – entire dive rule adds a safety factor if the diver is at shallower depths during most of the dive. Another safety factor inherent in table use is the rounding up to a depth or time value greater than the actual depth and time of the dive. By using 60 fsw when the maximum depth is 51 fsw additional safety is added.

Other disadvantages present themselves. A diver needs to read the device, understand the information that is being presented, and act upon that information. There is also the possibility that the DC will become a crutch. Some divers might use it as an excuse to not teach, learn, or use tables (just like BC's are being used to circumvent the teaching of proper weighting). The major disadvantage, shared by tables and DCs alike, is the fact that all the DC or table knows about is depth and time.

DECOMPRESSION MODELS VS REALITY

Decompression models do not actually represent what is happening in the body. All the models do is attempt to produce depth/time combinations that are safe for most divers most of the time. Nearly all decompression models to date use these two variables, depth and time. These used to compute the decompression status displayed to the diver. Many other factors can change the divers susceptibility to DCS. These include ascent rate, physical exertion, water temperature, physical condition, hydration level, blood alcohol, age, gender, breathing mixture, etc.

If two divers perform the same depth/time dive profile, one being low exertion by a young, healthy diver in a warm Caribbean environment and the other, performed in cold water by an older, out of shape, hung over diver, who was working heavily then the same decompression status will be computed by a DC (if the same DC model is used). All the DC "knows" is depth and time. A DC also has no memory of how it has reached its present decompression status. It does not keep track of the dive profiles that have been previously performed to modify decompression status calculations on subsequent dives. All it "knows" is the gas loading the model has calculated up to that point.

A MATHEMATICAL EQUATION DOES NOT A BODY MAKE! Divers must be aware that they need to add safety factors based on their own physiological state, the diving environment, and their previous dive profiles, just as they have been taught to do when using tables.

GENERAL MISUSES OF DIVE COMPUTERS

There seems to be some general techniques that have been developed by "clever" divers to squeeze every second they can out of a DC. The reasoning behind these abuses ranges from stupidity to blissful ignorance. Some of these misuses follow:

Regularly pushing unit to limits: There are many divers who run their DCs down to zero no-decompression time, ascend to a shallower depth, and then run the time back down to zero. This pushes the decompression model in the unit to its limit.

Ignoring ascent rate warnings: Most of the DCs use ascent rates that are slower than the 60 fsw/min. U.S. Navy standard. Using a faster ascent rate than suggested may place them outside the limits of the model. Following the slower ascent rates has the added benefit of requiring the diver to have good buoyancy control.

Not reading or ignoring the information: Some divers will just ignore the information provided by the computer if they do not like the information that is displayed.

Turning off unit to clear residual nitrogen: Some divers who do not like the repetitive dive information being shown by the DC will actually turn it off to clear the residual nitrogen from the computer's registers and give them more time on the repetitive dive. Clearing the residual nitrogen memory from the DC does not clear it from the diver's body!

Using outside operating range: About half of the DCs on the market are designed to be used at sea level or the first few thousand feet of altitude. The DCs based on the Swiss model generally adjust to altitude. However, some divers use the sea level DCs "as is" at altitudes outside the model's operating realm. Another problem in this category is diving to depths that exceed the maximum depth range of the DC. Why have a DC if it is being used on dives where it can't calculate properly or is placed in ERROR mode?

Abusing safety features: Some of the DCs have safety features that allow a diver to get out of situations outside the model or electrical limitations of the DC. Case in point, the EDGE DC has a maximum depth resolution of approximately 165 fsw. At that point the depth register is storing the largest number it can. If the diver were to descend further the DC would not be able recognize the fact that the diver was at a deeper depth. However, a safety feature was added that assumes that the diver is at approximately 200 fsw any time the maximum depth has been exceeded. This assumption will only be "safe" (which is a questionable term for any dive to that depth) for a minute or so. After that time the compartment pressure registers will reach the maximum value they can store and they will not be able to distinguish any increase in compartment pressure, making the calculations and decompression information erroneous. There are divers who pervert this safety feature to make dives to 200 fsw with the EDGE and some who use it to depths deeper than 200 fsw. Why? In most cases another diver has told them they could do it. Most of the time the divers don't really understand how the DC works, even though some think they do and they will believe what they want to believe.

Hanging the Dive Computer: One of the most ludicrous techniques observed. Some divers who violate the DC's ascent rate or have surfaced while the DC still indicates required decompression will tie a rope to the DC and hang it over the side of boat to clear the warnings and prevent the DC from going into ERROR mode. What can one say? The computer understands depth and time. It has no idea if it is attached diver or a rope.

Use with gas mixtures other than air: At this time all the DC models are based on the use of air as the breathing gas. Use of nitrox (enriched air) mixtures with less nitrogen content than air will theoretically add conservatism to the decompression calculations. However, the computers do not know anything about the increased potential of oxygen toxicity while using these mixtures. Other gas mixtures can actually increase the risk of DCS if decompression status is determined with an air based DC.

Blind trust in numbers: Many divers think that because the DC is telling them something that it is "TRUE." The numbers produced by the DC are only a guide to a divers decompression status, based on a decompression model using depth and time variables. The diver must be aware of the other factors that may influence susceptibility to DCS and add their own safety factors. As pointed out at the AAUS Dive Computer workshop last year, "They are like a small television, and people believe what they see on television."

Turn thinking over to a machine: Some divers do not want to worry, or think about their decompression status so they let a little box made out of silicon, metal, and plastic take over their thinking requirements. As stated before, the DC information is only a guide, not the gospel! Divers need to be able to think for themselves and understand the risks they are taking.

HOW DIVE COMPUTERS ARE BEING USED

In 1987 a group ten sport divers were monitored during a 14 day dive trip. All the divers, except one, used a DC. Following 76 of the dives the divers were monitored using Doppler ultrasonic bubble detector to check for "silent bubbles." On 65 dives the actual dive profile was recorded (maximum depth every 3 minutes).

When compared to the U.S. Navy tables 52 of the dives indicated omitted decompression. The maximum omitted decompression for a single dive was 71 minutes. The average was 23.0 minutes. For an entire day the maximum omitted decompression was 145 minutes and the average was 46.2 minutes The maximum time extended past the U.S. Navy No-Decompression limits was 55 minutes on a single dive (average of 23.8 minutes).

The profile data indicated that 48.5% of the dive time was spent at depths which were 75-100% of the maximum depth of the dive. 26.2% of the dive time was spent in the 50-75% of maximum depth range. 16.3% of the time was in the 25-50% range and only 9.0% was spent in the shallowest quarter of the dive. This indicates that, for this group of divers, the DCs were not being used to make a short excursion to a deep depth followed by the remainder of the dive in shallower water. Also, the profiles did not follow the deep-to-shallow rule as can be seen in Figure 2.

The results of the Doppler monitoring indicated one definite and three possible cases of Grade I bubbles. No symptoms of DCS were observed in the divers.

Mike Emmerman reported dive profiles used on the Andrea Doria (1). What he observed was frightening. Divers would do a 210 fsw dive, wait 4 to 6 hours, and then do the same dive over again. Some did two dives a day and others did three! This was done three days in a row. Over 50% of the divers used DCs. Some used DCs that had maximum depth ranges that were shallower than the depths of the dives. Of the 16 divers on the trip six of them presented definite signs and symptoms of DCS! These six divers did express some concern for their condition, but none of them sought treatment!

Dr. Tom Neuman at the University of California – San Diego related a case of DCS where a diver and his buddy had been diving with DCs (2). The dive history obtained from the diver was first a dive to 254 fsw followed by a dive to 160 fsw 3-1/2 hours later. Dr. Neuman found this hard to believe until it was discovered that the computer the diver wore also recorded the dive profile. The profile was recalled and the dives were confirmed, except for showing a maximum depth on the first dive of 230 fsw. This was due to the fact that the maximum depth limit for the computer was 230 fsw. However, when the dive log information was retrieved from the buddy's DC (one that has a depth limit of 300 fsw) a maximum depth of 254 fsw was obtained.

Another case involves a 26 year old male diver on vacation in the Caribbean using a DC.

On the day the problem developed the first dive was a multi-level dive to 140 fsw for a total dive time of 56 minutes. Four hours later a second dive was performed to 160 fsw for 47 minutes. The diver noticed an onset of fatigue 2 hours following the second dive, however he decided to perform a third dive following a 3 hour surface interval. This third dive was a night dive to 47 fsw for 67 minutes. That night he had a restless sleep, cold sweats, and minor pain in the elbow. In the morning the fatigue and pain remained so he proceeded to perform another dive. The dive was to 65 fsw for 40 minutes and during the dive felt pain relief. It was at this point that he concluded that he probably was bent. The next morning the pain and fatigue remained along with a headache. That day he flew home to the states and sought treatment, four days after the dive series that produced the problem. After being treated with a Table 6 treatment table the diver had no apparent residual problems. At all time the diver was within the "no-decompression" realm of his DC, but was pushing those limits.

The final case involved a 53 year old experienced female diver in excellent physical condition. She performed three dives to depths of 70 – 80 fsw using a DC. At no time was there less than 5 minutes of no- decompression time remaining on the DC. However, on the second dive the sleeve to her dry suit ripped exposing her arm to very cold water. Following the dive she had pain in her arm, but attributed it to the exposure to cold water. The suit was fixed and she performed the third dive. Later that evening, the pain in her arm became intolerable and she sought treatment. Besides the cold water another extenuating factor was that she had not had any hydration during the day (when she finally passed urine it was dark brown). There was no way for the DC to know that the dry suit had ripped or that the diver was dehydrated.

THE DIVER'S RESPONSIBILITY

Divers must realize that they need to take responsibility for their actions and safety. They must acknowledge the fact that every time they dive there is risk involved. One of these risks is the possibility of developing DCS. A diver needs to make a risk/benefit assessment as part of the dive plan. The goal of such an assessment is to maximize the benefit while minimizing the risk.

The operation and limitations of the DCs being used need to be understood. The more the diver understands about the equipment being used, the more educated and safe the decisions will become.

Dive computers should not be pushed to their limits. Divers should add safety factors just they are added with table use. Remember, all a DC knows about is depth and time. DCs are not anti-DCS talismans. They will not ward off bubble formation or suck the nitrogen from the body. Most of all, a diver needs to employ common sense in all phases of diving.

CONCLUSIONS

It should be remembered that the advent of reliable DCs should not give the "train em fast and easy" people in diving an excuse not to teach tables and underlying decompression concepts, nor should they provide lazy divers an excuse not to learn and practice table use. I have talked to instructors who would have no qualms about having their students just strap on a little box that tells them their decompression status instead of teaching the use of dive tables. There are places where Basic students are showing up to the first pool sessions wearing DCs. What incentive do they have for learning the concepts and use of dive tables? The introduction of DCs means that along with table instruction there is now the need to teach students how to use and understand computers.

No dive table or computer 100% effective! Divers need to understand how and where the numbers are coming from, be it with tables or computers. They need to realize that all these devices understand are depth and time applied to a mathematical model. Common sense and understanding need to be part of the equation. Dive computers are good tools and as such can be used to enhance the diving experience, but they are only tools, not demigods to be worshiped and followed religiously. With hard work, training, and education we may be able to eliminate the event where a diver states, "I don't understand, my computer told me I could..."

AAUS RECOMMENDATIONS

In October 1988 the AAUS held a workshop on the use of DCs in scientific diving (3). The recommendations that were agreed upon that apply to recreational divers are listed below:

A. *Each* diver relying on a DC to plan dives and indicate or determine decompression status must have their own unit.

B. On any given dive, both divers in the buddy pair must follow the most conservative DC.

C. If the DC fails at any time during the dive, the dive must be terminated and appropriate surfacing procedures should be initiated immediately.

D. A diver should not dive for 18 hours before activating a DC to use it to control his/her diving

E. Once a DC is in use, it must *not* be switched off until it indicates complete outgassing has occurred or 18 hours have elapsed, whichever comes first.

F. When using a DC, non-emergent ascents are to be at the rate(s) specified for the make and model of DC being used.

G. Ascent rates shall not exceed 40 fsw/min. in the last 60 fsw.

H. Whenever practical, divers using a DC should make a stop between 10 – 30 fsw for 5 min. especially for dives below 60 fsw.

I. Repetitive and multi-level diving procedures should start the dive, or the series of dives, at the maximum planned depth, followed by subsequent dives of shallower exposures.

J. Multiple deep dives should be avoided.

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2. Neuman, Tom, personal communications.

3. Lang, Michael A. and Hamilton, R.W., *Proceedings of the American Academy of Underwater Sciences Dive Computer Workshop*, University of Southern California Sea Grant Program, 1989.