UNDERWATER DECOMPRESSION COMPUTERS: ACTUAL VS. IDEAL

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As of this writing there are eleven underwater decompression computers (UDCs) being sold by nine different companies here in the U.S. There are, in actuality, only seven different types of UDCs and three general types of decompression algorithms being used in these devices. This presentation will examine the background of the decompression algorithms and their implementation in each of the devices. The variations of how the decompression (and other) information is displayed is presented. A discussion on how the models, and UDCs, relate to what is actually happening to the diver is presented. Future methods of UDC implementation are proposed along with additional features that could be implemented to provide scientific divers an ideal safety/research tool.

INTRODUCTION

At this time there are eleven underwater decompression computers (UDCs) available to the U.S. diving communities. This paper will look at the various devices, the theories and models they are based on, and the information they provide to the diver. The question of how the decompression model applies to the diver's actual decompression status will be examined. Finally, future implementations and functions that could be incorporated into UDCs will be discussed.

AVAILABLE COMPUTERS

Of the eleven UDCs available to divers at this time, there are only three different decompression models being used in these devices. Two of the models are based on no-decompression limits that have been determined by Doppler ultrasonic bubble detection (work of Spencer, Bassett, Pilmanis, and others). The other model is the Swiss decompression model developed by Dr. Bühlmann at the University of Zürich.

The following breakdown is of the eleven UDCs and the companies that distribute them, and the models on which they are based:

The EDGE:

The Edge is manufactured and distributed by ORCA Industries. The model it uses is a twelve compartment Haldanian model that is based on Doppler research. The compartment half-times range from 5 to 480 minutes. Every three seconds the "nitrogen pressure" in the compartments is updated based on the new pressure that is read through the pressure transducer.

In the Haldanian based UDCs the "on-gassing" and "off-gassing" of the compartments follow the same exponential rates. Any time the ambient pressure is greater than the compartment pressure, on-gassing occurs and if the compartment pressure is greater than the ambient pressure, nitrogen off-gassing occurs. The resulting pressure values in the twelve compartments are then used to compute the diver's decompression status.

The display on the EDGE is divided into graphical and digital information by a curve (limit-line) which represents the maximum pressure allowed in the twelve compartments (their M_o values). The display area above and to the left of the curve gives a bar graph representation of the pressures in the twelve compartments against a depth scale which runs vertically down the left side of the display. As long as all the compartment bars are above the limit-line the model is indicating a no-decompression dive and the diver can ascend directly to the surface. To the left of the depth scale is the depth bar which represents the divers actual depth and a maximum depth indicator. All the compartment bars will try to equilibrate to the same level as the depth bar. If any of the compartment bars have crossed the limit-line two "ears" start to move down the depth bar indicating the ceiling, or minimum depth, the diver can ascend to without violating the model. To decompress the compartments that have exceeded their M_o values the diver must ascend to a depth shallower than the M_o value of the violated compartment in order for the required off-gassing to occur.

The digital section of the display indicates the present depth of the diver, elapsed dive time, no-decompression/decompression time remaining, ceiling, and water temperature. The no-decompression/decompression time remaining display shows no-decompression time remaining as a positive number and decompression time remaining as a negative number. These times are based on the depth that the diver is at and the pressures in the twelve compartments. If the diver is in a no-decompression dive and ascends, the no-decompression time will increase due to the reduced pressure gradient between the ambient pressure and the compartments. If the diver moves into a decompression dive and will not be able to decompress at the present depth an "up-arrow" will be displayed, indicating the diver will need to ascend in order to decompress.

At the surface the display goes into surface mode. The graphical display will continue to indicate the compartmental pressures while the digital display will indicate additional information. The depth display will present the maximum depth of the last dive. The elapsed time display will alternate between the dive time of the last dive (in minutes and seconds) and the elapsed surface interval (in hours and minutes). The area which displayed the no-decompression/decompression time will scroll through the no-decompression times for repetitive dives to depths between 30 and 150 fsw.

Additional information will be displayed if the diver violates the recommended ascent rate (60 fpm [feet per minute] at depths deeper than 100 fsw, 40 fpm for depths between 60 fsw and 100 fsw, and 20 fpm for depths shallower than 60 fsw), if the diver ascends to a depth shallower than the ceiling, or if the diver exceeds the depth range of the device (approximately 160 fsw depending on the pressure transducer's calibration). When any of these situations occur a full screen warning will be alternated with the normal display.

Skinny Dipper:

The Skinny Dipper is also a product of ORCA Industries. It utilizes the same decompression model as the EDGE but uses a simpler display scheme. The display on the Skinny Dipper consists of three numerical segments (no graphics) and two LEDs. During a dive the top number of the display is the no-decompression time remaining. If a diver passes into a decompression dive the top number will convert to the ceiling depth. Since the Skinny Dipper was designed as a no-decompression computer it does not display decompression time remaining. Even though it does not display decompression information other than ceiling it blinks a message telling the diver to "go up" until a depth is reached where decompression can be achieved. The diver then waits until the ceiling reaches zero and then can surface. If the diver ascends to a depth shallower than the ceiling, the ceiling and depth displays will start to flash and the "Ceiling Alarm" LED will blink.

The middle number displays the present depth and the bottom number is the elapsed dive time. If the maximum depth of the unit is exceeded (199 fsw), an out-of-range display "or" will flash. If the diver is ascending faster than the recommended ascent rate the "Ascend Slower" LED will blink.

At the surface the Skinny Dipper scrolls through allowable repetitive dive time for depths between 30 and 130 fsw. The no-decompression time is displayed on the top line and the depth of the repetitive dive is the center number. The elapsed surface interval is presented on the last line. After the no-decompression time for 130 fsw is displayed, the unit shows a "log" screen for nine seconds. This screen presents the maximum depth and dive time of the last dive. On the top line a calculated time-to-fly is presented. This time-to-fly value represents the time it will take all the compartments in the model to reach a nitrogen pressure equivalent to 2 fsw or less.

Sigmatech:

The Sigmatech is distributed by Sherwood. It is a private labeling of the Skinny Dipper. Sherwood has incorporated it into a console along with a pressure gauge.

SME-ML:

The SME-ML is manufactured by Suunto of Finland and distributed by SeaQuest. It uses a nine compartment Haldanian model based on Doppler research. The half-time range of the compartments is 2.5 to 480 minutes. The display consists of four numbers, a depth bar graph, and five warning icons. During a dive the remaining no-decompression time is shown in the center of the screen. The depth is displayed at the top of the display and a depth bar descends along the scale on the left side. The dive time is shown at the bottom. A dive counter in the lower left corner shows how many dives have been done since the device was activated. If a diver enters a decompression dive, the ceiling is displayed by flashing the portion of the depth bar which is shallower than the ceiling and the required decompression time is shown in the center area along with an icon that indicates "Dec Time." If the ceiling is violated, another icon appears indicating the diver should descend. If the diver violates the ascent rate of 33 fpm a "Slow" icon will be displayed.

At the surface the unit scrolls through the no-decompression times for depths of 30 to 190 fsw. This will alternate with a display of the surface interval. A unique feature is that the device can be interrogated by touching its wet switches in a certain order. This produces a display of the maximum depth that was achieved every three minutes. The SME-ML stores ten hours worth of dive information that can be recalled at any time after the dive.

Datamaster II:

The Datamaster II is distributed by Oceanic. The decompression model it utilizes is pseudo-Haldanian, consisting of six compartments with half-times of 5 to 120 minutes. Its M_O values were based on no-decompression limits determined by Doppler studies. The difference between this model and the previous ones is that no off-gassing from the compartments is allowed while on a dive. Once a compartment reaches its highest pressure during a dive, it will remain at that pressure even though the ambient pressure may be less. Off-gassing will begin once the device reaches the surface.

The Datamaster II also calculates air consumption. It is attached via a high pressure hose to the pressure gauge port of the regulator's first stage. This allows the tank pressure to be displayed as well as air time remaining. The remaining air time is calculated based on the diver's average air consumption over a minute, the air requirements for an ascent at 60 fpm to the surface, and reaching the surface with 500 psi of pressure in tank.

The remaining no-decompression time shares display space with the remaining air time at the lower right corner of the screen. If the remaining dive time is controlled by the decompression model then a "NDC" icon is displayed next to the time. If the remaining air time is less than the no-decompression time an "AIR" icon is presented.

To the left of the remaining dive time display is the "Caution Zone." This presents a numerical and graphical representation of the last ten minutes of no-decompression time remaining. It is recommended by the manufacturer that a diver never surface with less than +5 minutes in the caution zone. If a value of less than +5 is displayed, then the diver should stop at 10 fsw until the display reaches +5. If the diver passes into a decompression dive, the caution zone number becomes negative. The diver will then need to stop at 10 fsw until a value of +5 is reached. Following a decompression dive the unit will not display any decompression information for twelve hours.

Continuing around the display in a clockwise direction is the present depth, maximum depth, water temperature, tank pressure, dive counter, and dive timer. When the diver surfaces, the display presents the surface interval time and computes a repetitive group letter based on the pressure of the 120-minute compartment. When the regulator is attached to a new tank, the display presents a scrolling display of no-decompression time from 30 to 130 fsw.

Data Scan II:

The Data Scan II (distributed by U.S. Divers) and the Datamaster II are the same unit with different display configurations. The Data Scan II presents the same information (except for temperature) as the Datamaster II, plus a bar graph representation of the tank pressure.

Decobrain II:

The Decobrain II (manufactured and distributed by Divetronic) is based on the 16 compartment Swiss model (ZHL-12) developed by Dr. Bühlmann at the University of Zürich. The half-times of the compartments range from 4 to 635 minutes. This unit is designed for altitude diving up to 4500 meters above sea level. It adjusts its M_O values based on the altitude it is being used at. During the dive the unit displays the no-decompression time remaining and flashes the time when within five minutes of the no-decompression limit. If a decompression dive is performed, the first decompression stop is displayed along with the "shortest safe ascent time." The depth and dive time are displayed with the maximum depth displayed twice a minute for two seconds. An ascent rate LED will start to flash if an ascent rate of 10 mpm (meters per minute) (33 fpm) is exceeded.

At the surface when the unit is turned on, it will display the atmospheric pressure in millibars and then will scroll through the no-decompression limits for 30 to 100 fsw. After a dive, it will display the maximum depth and bottom time of the dive, the surface interval required before flying, and the total time to eliminate all the residual nitrogen from the compartments.

Micro Brain:

The Micro Brain is also manufactured by Divetronic but is distributed by Dacor. The model it uses has six compartments that corresponds to the 16 compartment Swiss model. It can be used as a decompression computer to altitudes of 1500 meters above sea level. During the dive, the no-decompression information is presented as a decreasing wedge at the bottom of the display. The wedge consists of seven bars that disappear as the no-decompression time decreases. These bars have values of ++, 30, 15, 8, 4, 2, and 0 minutes. Along with the wedge, the dive time and actual depth is displayed. If a decompression dive is performed, the depth of the first decompression stop is alternated with the depth display every five seconds for a second along with a "Deco Stop" icon and an "Ascend" warning. If the diver ascends past the decompression stop, a "Descend" icon is displayed.

At the surface the no-decompression times for depths from 49 to 135 fsw are scrolled through. The maximum depth and dive time of the last five dives can be recalled using a wet switch. A "Do Not Fly" icon is presented while the model indicates that it is not safe for the diver to fly.

Uwatech:

Uwatech of Switzerland manufactures an UDC for its own distribution as the Aladin. This UDC is also distributed by Beuchat as the G.U.I.D.E. and Parkway as the Black Fox. The decompression algorithm used in this unit is a twelve compartment version of the Swiss model. The Uwatech UDC utilizes four sets of M_O values based on the altitude range the dive is conducted in. These ranges are 0-2470, 2470-5100, 5100-8555, and 8555-13200 feet above sea level. During a dive the no-decompression information is presented, in minutes, as a negative number in the lower right corner of the display. If a diver enters a decompression dive, the unit will flash "DEC" in the decompression information display along with the depth of the first decompression stop. Once the diver reaches the first decompression stop, that depth will continue to flash until it is time to ascend to the next stop which will be displayed. If the diver ascends past the required decompression stop, a flashing "DOWN" icon will be displayed along with a down arrow to indicate the diver needs to descend. Along with the decompression information the diver's present depth is displayed in the upper left area of the screen and below it, the maximum depth attained during the dive. The total dive time is displayed above the decompression information area.

After the dive the unit will present the maximum depth of the last dive and the elapsed surface interval. The Uwatech UDC can be interrogated and the log entries for the last five dives can be recalled by activating two wet switches.

THEORIES AND MODELS VS. REALITY

One major misconception that is still held by many divers who use UDCs is that they monitor, or model, exactly what is going on in the body. A UDC, like a set of decompression tables, can only be used as a guide based on a theoretical decompression model. The ability of a model to produce safe profiles may or may not have anything to do with how accurately the model describes the mechanics of nitrogen on-gassing and off-gassing during those profiles.

In all decompression models the major (and in almost all cases the only) variables that are considered are depth and time. UDCs compute their decompression status based solely on these two variables. Thus, the decompression status computed by a UDC does not take into account water temperature, physical exertion, ascent rate (even though it is monitored in some cases), the divers physical condition, age, sex, hydration level, etc. All these variables are considered to effect the divers susceptibility to decompression sickness (DCS). The result is that a strenuous dive to a specific depth in a cold water environment will produce the same decompression status in a UDC as a low exertion dive to the same depth in a warm Caribbean environment. To counter these factors the diver must assume the responsibility of adding safety factors to their dives while using UDCs, just as they have been added in the past while using tables. UDCs are not talismans that will guarantee that the diver will not develop decompression sickness. They must be used with common sense and the diver must be aware of the potential of developing DCS during any dive.

Another area where the UDC may deviate from reality (or what the UDC perceives as reality) deals with the accuracy of the pressure transducer. As depth gauges, UDCs have proven to be much more reliable than mechanical depth gauges. Their accuracy, in the worst cases, is listed at +/- 2 fsw (+/- .6 msw). During a dive an UDC could read in a depth that is 2 fsw shallower than the actual depth. If this occurs, then the compartment pressures that are calculated will be less than the actual pressures that should have been calculated. The UDC is computing a less strenuous decompression status than it should be. Preliminary calculations indicate that a reduction of the M_O values to 95% of their current values would adjust for the potential transducer error. This would have the effect of reducing the no-decompression limits as much as 20% in the shallower depth ranges and hardly any reduction at deeper depths.

FUTURE CONFIGURATIONS OF UDCs

With the growing acceptance of UDCs, the ability to incorporate additional features seems to be limited only by imagination and technology. Two functions that should be available soon will be the ability of an UDC to communicate with a personal computer (PC) and full dive profile recordings. The ability to communicate with PCs will permit easy reprogramming of the UDC if modifications are made to its software. The PC could also be used as a diagnostic tool by being able to interrogate the various components of the UDC. Along with these functions the ability to "talk" to a PC presents an easy way to log dive information. By incorporating additional memory into the UDC, the actual depth of the dive could be recorded every few seconds. After the dive this information could be downloaded into the PC and the actual dive profile displayed along with any other recorded information from the dive. This dive profile information would be very valuable in decompression research or in the treatment of a diver who has developed DCS.

Another feature that could easily be incorporated into an UDC would be a safety factor multiplier based on various environmental and physical variables such as water temperature, diver exertion level, actual ascent rate, age, etc. Information on the diver could be entered via the PC and other information obtained from additional sensors in the UDC. The major problem with the implementation of this feature would be the determination of the safety factors for these additional variables. At present, there is no quantitative correlation between these variables and their increasing or decreasing the risk of DCS.

Perhaps the ultimate UDC would be one that actually monitors the gas absorption and elimination in the diver throughout the dive. This would allow all dive profile decompression status information to be determined by the actual system (the diver) the UDC is designed to protect.

Additional advanced features not related to decompression could be incorporated into the UDC for scientific and other types of diving. By using a LCD television type display, output information could achieve a high degree of flexibility.

One possible application would be a sonar unit for low visibility diving. The device would be able to display the distance from the diver to an object that produced a reflection during a scan. If the display is in color, the hardness of the reflection could be color-coded.

Another pictorial application could display the diver's location with respect to fixed beacons. This positioning system could be valuable in following search and survey grids or in marking points of interest. If the position information is recorded, along with depth, and dumped to a PC, then a three-dimensional trace of the profile could be obtained.

Other information could be recorded with additional types of sensors. Temperature, salinity, and dissolved oxygen sensors could be incorporated and their values recorded along with depth, position, and time.

CONCLUSION

With the eleven UDCs available there are three basic decompression models being used. The major differences within the the devices using the same model are in amount and format of the information that is displayed to the diver.

Although the technology of UDCs is improving rapidly, and in the future we can expect to see more sophisticated devices with additional functions and features, it must be remembered that as long as the decompression status is based on a model it does not necessarily represent the diver's actual decompression status.

The time is ripe to discuss the possibility of new types of UDCs with the manufacturers. There is the potential for incorporating additional sensors and functions into the UDCs to develop a device that could be used to collect valuable scientific data. Whether or not the manufacturers will take the suggestions and incorporate them is not known, but they won't know what type of data is needed or collected if they aren't told.