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A review of the technical specifications of 47 models of diving decompression computer

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Abstract

Many modern diving decompression computers have the ability to record and display information of, and related to, the dive profile. In the UK, there are currently approximately 50 models of diving decompression computer being sold with a capability for recording and downloading dive information. Based on the technical information either supplied with each computer or made available on the internet this present study presents examples of 47 of these downloadable computers to review some of the parameters that are commonly measured, recorded and/or displayed such as: depth recording and/or measurement frequency, and/or measurement resolution, method of recording/display (e.g. maxima, minima, average, thresholds), methods of downloading information, and what data are stored and storage limitations. Although there is a wide range in the technical capabilities of the computers reviewed they all record and store similar basic dive profile information. However, the present review highlights the variation in many of the recording/measuring formats and download methodologies.

Keywords: dive computer, decompression computer, technical specifications, review, SCUBA

1. Introduction

Dive computers that calculate and display decompression information for divers have been evolving in their accuracy and complexity for a number of decades (Lang and Hamilton, 1988; Loyst et al., 1991) and have been capable of recording dive profile information in a practical and user-friendly fashion since the early 1990s (Sayer et al., 1998). Inevitably, as the performance of micro-computation has developed over recent years the type and volume of information being calculated, displayed and stored has increased with, in some cases, the dive computer offering higher levels of operational complexity with concomitant decreases in overall size. Some modern dive computers can remotely monitor external features such as gas use and/or heart rate (e.g. Angelini et al., 2007), and/or incorporate the changing of gas mixtures and/or the use of closed or open-circuit operations in their calculations (e.g. AP Valves, 2003). These technological advances mean that dive computers are now capable of delivering high-quality information with usage as diverse as marine biology (Collins and Baldock, 2007), pathology (Rutty, 2006), decompression modelling (Sayer et al., 2005) and dive accident investigation (Sayer et al., 2008).

In the recreational sector, the use of computers to manage dive decompression is probably approaching 100% and their use is also widespread in other diving sectors (such as occupational scientific diving). However, apart from relatively basic reviews in the sport diving literature, little information exists on which to base comparative assessments of the respective technical features of the current models of dive decompression computer. In recent years there has been a rapid expansion in the number of manufacturers and models of dive computer. In the UK at present there are over 50 models of diving computer from 14 manufacturers being marketed or have only recently been discontinued (and so remain in widespread use).

This present study reviews all the technical literature available for a selection of 47 models of diving decompression computers to provide an understanding of the technical specifications of each model on which to base comparisons. This present study only includes models of dive computer that are capable of storing dive profile information which can be downloaded subsequently. The review relies heavily on the manufacturer's manuals that are either provided with the computer or available for download *via* the internet. Where possible, this review cites the most recent version of any particular manual and gives the online address for ease of access. The manuals frequently do not include a date of publication (denoted here as n.d. = no date) but can be tracked by title, web address, or version code.

2. Methods

A review of recent trade literature and trade websites was used to establish the number of dive decompression computer models currently on sale in the UK that were capable of storing and offloading dive profile information. To maintain an independence from the manufacturers, 45 models of dive decompression computer were purchased from a range of suppliers; two models already available were added to the study as they represented models that were no longer available for purchase but used widely.

Technical information was gained largely from the operating manual of each model. In cases where the manuals did not provide the necessary information, contact was made with support centres or technicians. For ease of reference and comparison, the parameters examined were only at the level of maximum commonality between all 47 models. The examinations were divided into three groups: aspects of data recording and computer storage capacity; methods of decompression management employed; and user alterations that could be made to the computer settings as well as any notable or innovative features.

All the computer models were downloaded to test the transfer methodology and to view the data stored.

3. Results

3.1. Data recording and storage capacity

3.1.1. Recording intervals and data storage capacity

For many models of dive computer examined in this present study there were differences between how and when the computers take measurements of various parameters and how and when those data are recorded and/or displayed. Information on measurement frequency, resolution and accuracy is rarely if ever made available in the sources reviewed here. Therefore, this section only refers to the frequency and resolution of data that were displayed and/or stored.

The time intervals that the computers can be set to record and/or display data ranged from 1 second to 180 seconds (Table 1). Some of the computers permitted user modification of this recording interval. For example, the newer *Suunto* models such as the D9, D6, D4, Cobra 2 and 3 as well as the Vyper 2 and Vyper Air could all be set to 1s, 10s, 20s, 30s or 60s intervals. The older *Suunto* computers such as the Vytec and the Cobra could be set to record data every 60s, 30s, 20s or 10s. Other computers with this user adjustable data recording frequency included the *Oceanic* models, the *Tusa* Hunter, both *Apeks* computers and the *Seeman* XP5.

Other models had fixed data recording limits with recording/display intervals that ranged from 4 seconds to 3min (Table 1). Examples of the former were the new *Uwatec* Galileo Sol and Galileo Terra. The *Uemis* SDA displayed readings every 5s while the *VR3* and *VRX* recorded data every 10s. *Mares* models recorded data every 20s while the *Cressi Sub* Archimede II and Edy II recorded every 30s. Finally, the *Buddy* Nexus only recorded dive data every 3min which was a significantly longer interval than any of the other models available.

Although there was no set standard when it came to the recording intervals of the computers, there was wide scope for owner adjustment in a number of the models. Consequently the storage capacities of the computers, which were largely dependent on the amount of data recorded, were difficult to define; for example, in some cases, storage capacity increased as the intervals between recordings were increased. Storage capacity was sometimes given as a time limit, sometimes as the number of dives stored and sometimes as both (Table 1). The storage capacity of the computers that had a fixed recording interval still covered a wide range. The *Buddy* Nexus only stored up to 10 hours of detailed information or data from 10 dives even with a measurement interval of 3min. The *Mares* models stored 36–40 hours of information and the *Uwatec* Galileo Sol and Terra had a capacity of 100h with 4s recording intervals. This was more than the VR3 which could store 99 dives or 22 hours of detailed profile information at 10s intervals; the VRX examined in the present study stored 20 hours, although the memory of these models varied from 8 to 80 hours depending on the model and features of each computer (VR Technology Ltd., *pers. comm.*). In comparison, the *UEMIS* SDA had an enormous storage capacity of around 2,000 dives.

3.1.2. Depth recording and measurement

Depth recording is one of the basic functions of any dive computer and the resolution of the measurements displayed ranged from 0.1m to 0.5m in the models discussed here (Table 1). Although the dive computers displayed depth measured in a number of ways and over a range of resolutions, the units were probably measuring depth (in the form of pressure measurements) at different rates and resolutions for the decompression calculations. For example, although the *UEMIS* only displayed the point depth at 5 second increments when downloaded, the unit actually took pressure measurements at 625ms increments for use in the decompression algorithms (UEMIS, *pers. comm.*).

It is clear from Table 1 that the vast majority of computers displayed depth in 0.1m increments. However, the *Buddy* Nexus displayed at increments

Table 1: Depth recording formats and data storage capabilities of 47 models of downloadable diving decompression computers as retrieved from the relevant technical manuals. Spaces indicate where no information was found or was unclear; depths have been converted to metric equivalents in some cases; depth recording method indicates how depth is represented in the download per recording interval being the maximum depth recorded in that interval (max), the average depth for that interval (average), or the actual depth being measured at the last moment of the recording interval (point)

Brand	Model	Depth resolution (m)	Sample rate/ recording intervals (s)	Depth recording method	Data storage (dive #, or time)	Reference
Uwatec	Galileo Sol	0.1	4	Max	99/100h	Scubapro-Uwatec (n.d.-a)
Uwatec	Galileo Terra	0.1	4	Max	99/100h	Scubapro-Uwatec (n.d.-b)
Uwatec	Smart Tec	0.1		Max	100h	Scubapro-Uwatec (n.d.-c)
Uwatec	Smart Com	0.1	4	Max	50h	Scubapro-Uwatec (n.d.-d)
Uwatec	Aladin Pro Ultra	0.1	20	Max	37/200min	Scubapro-Uwatec (n.d.-e)
Uwatec	Aladin Tec 2 G	0.1	4	Max	25h	Scubapro-Uwatec (n.d.-f)
Uwatec	Aladin Prime	0.1	4	Max	25h	Scubapro-Uwatec (n.d.-g)
Uwatec	Aladin One	0.1	4	Max	25h	Scubapro-Uwatec (n.d.-h)
Scubapro	Xtender	0.1	30	Max	30 dives	Scubapro-Uwatec (n.d.-i)
Mares	Nemo	0.1	20	point	36h	Mares (2005)
Mares	Nemo Sport	0.1		average	30 dives	Mares (2007)
Mares	Nemo Air	0.1	20	point	36h	Mares (2008a)
Mares	Nemo Excel	0.1	20	point	36h	Mares (2008b)
Mares	Nemo Wide	0.1	20	point	40h	Mares (2008c)
Mares	Puck wrist	0.1	20	point	40h	Mares (2008d)
Mares	Puck Air	0.1	20	point	40h	Mares (2008e)
Suunto	D9	0.1	adjustable to 1	Max	Approx. 36h	Suunto (2006b)
Suunto	D6	0.1	adjustable to 1	Max	Approx. 36h	Suunto (2006c)
Suunto	D4	0.1	adjustable to 1	Max	Approx. 80h	Suunto (2007b)
Suunto	Stinger	0.1	20	Max	Approx. 80h	Suunto (2006d)
Suunto	Spyder	0.1	20	Max	36h	Suunto (n.d.-b)
Suunto	Vytec DS	0.1	adjustable to 10	Max	Approx. 36h	Suunto (2005)
Suunto	Cobra	0.1	adjustable to 10	Max	Approx. 36h	Suunto (2006a)
Suunto	Cobra 2	0.1	adjustable to 1	Max	Approx. 42h	Suunto (2007c)
Suunto	Cobra 3	0.1	adjustable to 1	Max	Approx. 42h	Suunto (2008a)
Suunto	Vyper	0.1	20	Max	36h	Suunto (2006e)
Suunto	Vyper 2	0.1	adjustable to 1	Max	Approx. 42h	Suunto (2007a)
Suunto	Vyper Air	0.1	adjustable to 1	Max	Approx. 80h	Suunto (2008b)
Tusa	DC Sapience	0.5	30		60 dives/30h	Tusa (2004b)
Tusa	DC Hunter	0.5	15 or 30		60 dives/30h	Tusa (2004a)
Oceanic	Veo 250	0.1	adjustable to 2	Max	24 dives	Oceanic (2002b)
Oceanic	VT 3	0.1	adjustable to 2	Max	24 dives	Oceanic (2006)
Oceanic	Pro Plus 2	0.1	adjustable to 2	Max	24 dives	Oceanic (2002a)
Oceanic	Atom 2	0.1	adjustable to 2	Max	24 dives	Oceanic (2005)
Oceanic	Datamask Hud	0.1	adjustable to 2	Max	24 dives	Oceanic (2007)
AP Valves	Buddy Nexus	0.3	180	Max	10 dives/10h	AP Valves (2003)
Citizen	Cyber Aqualand NX	0.1	1	point	100 sets	Citizen (n.d.)
Cressi Sub	Archimede 2		30	Max	30h/60 dives	Cressi Sub (n.d.-a.)
Cressi Sub	Edy II	0.1	30	Max	30h/60 dives	Cressi Sub (n.d.-b.)
Beuchat	Voyager	0.1	adjustable to 2		24 dives	Beuchat (2004)
Apeks	Quantum	0.5	15 or 30	point	30h/60 dives	Apeks (2003a)
Apeks	Pulse		15 or 30	point	30h/60 dives	Apeks (2003b)
VR Technology	VRX	0.1	10	point	20h	VR Technology (2009)
VR Technology	VR 3		10	point	99 dives/22h	VR Technology (2009)
Seeman	XP5	0.1	adjustable to 2s		24 dives	Seeman (2004)
Uemis	SDA		5	point	2,000 dives	Uemis (2009)

of 0.3m while the *Tusa* Sapience and Hunter both displayed at a resolution of 0.5m.

The recording format used by each model was described very rarely in any of the manuals. The term 'recording format' was used to refer to how a depth measurement was recorded, stored and later displayed within a set time interval. For example, in a displayed 20s recording period a dive computer might record and display the depth measured at the 20th second, the maximum or minimum depth reached within the 20s, or the average depth the diver was at within those 20s. *Uwatec*, *Suunto*, *Oceanic*, *AP Valves* and *Cressi Sub* models all recorded the maximum depth reached at any time during the recording period. The *Mares*, *Citizen*, *Apeks* and *VR Technology (Delta P)* models displayed the depth the diver was at when the depth measurement was recorded. However, on download, the *Mares* Nemo Sport gave the average depth reached in the recording interval.

3.1.3. Temperature recording and measurement

The temperature recording and resolution of the computers is not shown in Table 1 as the vast majority of computers recorded to a resolution of only 1°C. There were, however, a few exceptions with the *Scubapro* Xtender and the *Mares* Nemo Sport recording to 0.1°C and the *Cressi* models recording to 0.5°C.

3.2. Dive time and decompression

3.2.1. Decompression models

In the supporting technical literature, manufacturers and/or suppliers often referred to a particular algorithm series or type as being ''modified''. An underlying demand for diving computer designers and engineers is that the computational power of small, wrist-based computers is not sufficient to run full versions of many decompression algorithms. Therefore, ''modifications'' are often a choice of reducing the full power of the chosen or purchased algorithms to fit the available capacity of the computer. There is no information available to indicate what alterations to an algorithm series have been employed for any computer using a ''modified'' decompression model.

The dive computer models marketed by *Tusa*, *Cressi Sub*, *Apeks* and *AP Valves* all based their decompression management on modified Bühlmann algorithms that were based on relatively simple gas uptake and elimination rates over a range of mathematical compartments that attempt to mimic the behaviour of a similar range of body tissues (Table 2). However, as is shown in Table 2, different computers used a different number of tissue compartments and different tissue half-times. No information was obtained for the half-times employed in the *Tusa* DC Sapience and DC Hunter. The *Buddy* Nexus and both the *Apeks* Pulse and Quantum used similar half times that ranged from approximately 5–480min. The *Cressi Sub* Archimede II and Edy II computers had more slow tissue groups and the ones they model ranged from 5 to 640min. All of these computers claimed to use a modified Swiss or Bühlmann algorithm but none stated what component of the original algorithms was being modified in their decompression calculations or, indeed, how.

The *Oceanic*, *Beuchat* and *Seeman Sub* computers used models based on Haldanian theories but their algorithms were modified according to the DSAT (Diving Science and Technology) tables (Table 2). The DSAT tables used 8 tissue compartments with half times of 5–120min (Lippmann and Mitchell, 2005). However, in the present study, all the computer models that stated employing DSAT modifications used tissue half-times of 5–480min. All of the dives carried out in the DSAT study were shallower than 27m with no decompression dives and so all of the DSAT-modified computer models rely on US NAVY decompression theory to compute and/or extrapolate decompression for dives that fall outside of these boundaries (Beuchat, 2004; Seeman, 2004; Oceanic, 2009).

The *Citizen* Cyber Aqualand Nx computer used DCIEM (Defence and Civil Institute of Environmental Medicine) algorithms for decompression management (Table 2). In contrast, *Suunto* and *Mares* incorporated Reduced Gradient Bubble Models (RGBM) into their computers. RGBM compute the theoretical uptake of soluble gas by the body's various tissues but also take free phase gas bubbles that may be found in the blood into account and try to limit their development and growth (Weinke and O'Leary, 2002). No manufacturer referred to the model simply as RGBM but either as, for example, *Suunto* RGBM or *Mares–Weinke* RGBM. The version of the RGBM model incorporated in *Suunto* computers is a Haldane decompression model with added bubble controlling or limiting factors (Weinke and O'Leary, 2002). One feature of bubble models is that they produce decompression stops deeper than those traditionally employed by earlier decompression theories on similar decompression schedules in order to try and limit bubble formation on ascent. All of the *Mares* models gave deep stops as part of the ascent if necessary; some *Suunto* models such as the D9, D6, Vytec DS, Cobra 2 and 3, Vyper 2 and Vyper Air also gave deep stops but in their case the user could choose whether to do these or the more traditional shallower safety stops.

The basic decompression algorithm set used in the *Uwatec* computers was an adapted Bühlmann one and, as such, was based on modelling tissue gas uptake and elimination rates. However, a number of models such as the Aladin Tec 2G, Smart Com, Smart Tec, Galileo Terra and Galileo Sol also incorporated a micro bubble function. For example, the Galileo Terra had an algorithm defined as ZH-L8 ADT MB PDIS (Table 2). The ZH-L8 refers to the algorithm set Bühlmann developed in Zurich (ZH) which employed 8 'M' values or

Table 2: The methods of decompression management employed by 47 models of downloadable diving decompression computers as retrieved from the relevant technical manuals. Spaces indicate where no information was found or was unclear. Many companies employ undisclosed modified (mod.) versions of standard algorithms. Bühlmann algorithms are denoted as Zurich (ZH), limits (L) and the number of M-value sets, ADT = Adaptive, MB = Microbubble, PMG = Predictive Multi-Gas, PDIS = Profile Dependent Intermediate Stop; RGBM = Reduced Gradient Bubble Model; DSAT = Diving Science and Technology; DCIEM = Defence and Civil Institute of Environmental Medicine; VGM = Variable Gradient Model; VPM-B = Varying Permeability Model B

Brand	Model	Decompression model	Tissue groups	Half times (min)	Ascent rate	Reference
Uwatec	Galileo Sol	ZH-L8 ADT MB PMG	8	5–640	variable	Scubapro-Uwatec (n.d.-a)
Uwatec	Galileo Terra	ZH-L8 ADT MB PDIS	8	5–640	variable	Scubapro-Uwatec (n.d.-b)
Uwatec	Smart Tec	ZH-L8 ADT MB PMG	8		variable	Scubapro-Uwatec (n.d.-c)
Uwatec	Smart Com	ZH-L8 ADT MB	8	5–640	variable	Scubapro-Uwatec (n.d.-d)
Uwatec	Aladin Pro Ultra	ZH-L8 ADT	8	5–640	variable	Scubapro-Uwatec (n.d.-e)
Uwatec	Aladin Tec 2 G	ZH-L8 ADT MB PMG	8	5–640	variable	Scubapro-Uwatec (n.d.-f)
Uwatec	Aladin Prime	ZH-L8 ADT	8	5–640	variable	Scubapro-Uwatec (n.d.-g)
Uwatec	Aladin One	ZH-L8 ADT	8		variable	Scubapro-Uwatec (n.d.-h)
Scubapro	Xtender	Modified Swiss	9		variable	Scubapro-Uwatec (n.d.-i)
Mares	Nemo	RGBM Mares-Weinke	10		10m/min	Mares (2005)
Mares	Nemo Sport	RGBM Mares-Weinke			10m/min	Mares (2007)
Mares	Nemo Air	RGBM Mares-Weinke	10		10m/min	Mares (2008a)
Mares	Nemo Excel	RGBM Mares-Weinke	10		10m/min	Mares (2008b)
Mares	Nemo Wide	RGBM Mares-Weinke	10		10m/min	Mares (2008c)
Mares	Puck wrist	RGBM Mares-Weinke	10		10m/min	Mares (2008d)
Mares	Puck Air	RGBM Mares-Weinke	10		10m/min	Mares (2008e)
Suunto	D9	Suunto RGBM	9	2.5–480	10m/min	Suunto (2006b)
Suunto	D6	Suunto RGBM	9	2.5–480	10m/min	Suunto (2006c)
Suunto	D4	Suunto RGBM	9	2.5–480	10m/min	Suunto (2007b)
Suunto	Stinger	Suunto RGBM	9	2.5–480	10m/min	Suunto (2006d)
Suunto	Spyder		9	2.5–480	10m/min	Suunto (n.d.-b)
Suunto	Vytec DS	Suunto RGBM	9	2.5–480	10m/min	Suunto (2005)
Suunto	Cobra	Suunto RGBM	9	2.5–480	10m/min	Suunto (2006a)
Suunto	Cobra 2	Suunto RGBM	9	2.5–480	10m/min	Suunto (2007c)
Suunto	Cobra 3	Suunto RGBM	9	2.5–480	10m/min	Suunto (2008a)
Suunto	Vyper	Suunto RGBM		2.5–480	10m/min	Suunto (2006e)
Suunto	Vyper 2	Suunto RGBM	9	2.5–480	10m/min	Suunto (2007a)
Suunto	Vyper Air	Suunto RGBM	9	2.5–480	10m/min	Suunto (2008b)
Tusa	DC Sapience	Swiss mod.	12			Tusa (2004b)
Tusa	DC Hunter	Swiss mod.	12			Tusa (2004a)
Oceanic	Veo 250	DSAT	12	5–480	variable	Oceanic (2002b)
Oceanic	VT 3	DSAT	12	5–480	variable	Oceanic (2006)
Oceanic	Pro Plus 2	DSAT	12	5–480	variable	Oceanic (2002a)
Oceanic	Atom 2	DSAT	12	5–480	variable	Oceanic (2005)
Oceanic	Datamask Hud	DSAT	12	5–480	variable	Oceanic (2007)
AP Valves	Buddy Nexus	Bühlmann mod.	8	5–480	variable	AP Valves (2003)
Citizen	Cyber Aqualand NX	DCIEM			18m/min	Citizen (n.d.)
Cressi Sub	Archimede 2	Bühlmann ZH-L8 mod.	12	5–640	variable	Cressi Sub (n.d.-a.)
Cressi Sub	Edy II	Bühlmann ZH-L12 mod.	12	5–640	variable	Cressi Sub (n.d.-b.)
Beuchat	Voyager	DSAT	12	5–480	variable	Beuchat (2004)
Apeks	Quantum	Bühlmann mod.	12	5–473	variable	Apeks (2003a)
Apeks	Pulse	Bühlmann mod.	9	5–473	variable	Apeks (2003b)
VR Technology	VRX	VGM; VPM-B with Bühlmann	16 (VGM)	4–635 (VGM)	10m/min	VR Technology (2009)
VR Technology	VR 3	Bühlmann ZHL-16 mod.	16	4–635	10m/min	VR Technology (2009)
Seeman	XP5	DSAT	12	5–480	variable	Seeman (2004)
Uemis	SDA	Uemis ZH-L8+	8	5–640	10m/min	Uemis (2009)

theoretical tissue compartments (L8; Lippmann and Mitchell, 2005). The algorithm set was adaptive (ADT) to incorporate micro bubble formation (MB) with Profile Dependent Intermediate Stops (PDIS) to limit micro bubble growth. Similarly, the *Uemis* SDA also used a Bühlmann algorithm set, the ZH-L8+, which computed gas uptake and elimination for 8 tissue compartments with half times that ranged from 5 to 640min. The *Uemis* also had a micro bubble modelling capability and could also produce deep stops if commanded.

The *VR Technology (Delta P)* computers, the VR3 and the VRX, were unlike any of the other computers in the present review in that they permitted the user a large degree of control over the performance of the supplied decompression algorithms. Both computers used an algorithm set that was derived from the Bühlmann ZH-L16 model based on tissue saturation dynamics but it also incorporated micro bubble reduction modelling and deep stops (Table 2). The VR3 computer also worked on a second algorithm series that included a varying permeability model (VPM). It was possible to have both of these algorithms on the same unit at the same time. The decompression schedule, tissue loading and bubble formation for a particular dive were calculated by both algorithm types. The user could then change the selected algorithm type between dives and before desaturation. The VRX computer offered the same capability with the addition of *VR Technology's* new Variable Gradient Model (VGM). In addition to this, the VRX also allowed users to adjust the level of conservatism by adjusting the saturation tolerance values for fast, mid and slow tissue groups separately, giving any individual diver control over their own decompression although it is unclear as to how divers inform their decisions. This is not dissimilar to many of the other models examined here where users could alter parameters that would alter decompression management directly or indirectly. Direct changes in conservatism are usually through a limited series of un-quantifiable conservatism settings; these may be influenced further by changing altitude and/or decompression model settings.

3.2.2. Ascent rates

Ascent rates were another component of decompression management and, again, most manufacturers approached this feature differently (Table 2). *Uwatec, Oceanic, Cressi Sub, Apeks, Seeman, AP Valves* and *Beuchat* computers all employed variable ascent rates with faster rates of ascent allowed at depth (often unspecified) and slower rates as the diver moved into shallower water. In contrast, *Suunto, Mares, VR Technology (Delta P)* and *Uemis* computers used a maximum ascent rate of 10m per minute from all depths. The *Citizen* Cyber Aqualand differed in that it also had a uniform ascent rate but this was up to 18m per minute (Table 2). Some computers, for example, the *Tusa* Sapience and Hunter, monitored ascent rates but did not provide any information as to what values they were using to do so.

3.3. Settings

3.3.1. Gas mixes

All of the models, except the older *Suunto* Spyder, could calculate decompression schedules for both air and nitrox gases (Table 3). The VR3 and the VRX also had a trimix capability. The information in Table 3 shows that eleven of the computers could take two different gas mixes per dive, eight could monitor up to three and the VR3 and the VRX could manage decompression for up to ten different gas mixes per dive.

3.3.2. User settings

All of the computers permitted some form of manual alteration to some of their settings (Table 3). The majority of them permitted the diver to allow for personal factors by applying different levels of conservatism. The exceptions to this were the *Aladin* One and the *Beuchat* Voyager; it was unclear as to whether this was also the case for the *Uwatec* Aladin Pro Ultra, the *Citizen* Cyber Aqualand and the *Oceanic* Veo 250.

The *Buddy* Nexus, *Suunto* computers and the *Mares* models, apart from the Nemo Sport, also allowed manual adjustment of the altitude level (Table 3). All of the other models under review adjusted the altitude level automatically.

Another setting that could be manually altered in some of the computers was the water type. The *Mares, Tusa, Apeks, Uemis* SDA, *Uwatec* Galileo Sol, Galileo Terra and Tec 2 G all allowed this to be changed to fresh or sea water. The *Buddy* Nexus also allowed the user to change the water type but this was achieved by increasing or decreasing the salinity percentage. The *Suunto* computers under review here did not have this function and were calibrated to ''salt water'' as were the *Cressi* models, the *Citizen* Cyber Aqualand Nx, *Scubapro* Xtender and the *Uwatec* Aladin Prime and Aladin One; however, there was no information in the available literature on what standards had been used for ''sea water'' calibration. Conversely, the *Uwatec* Smart Tec, Smart Com and Aladin Pro Ultra were fresh water calibrated. It is claimed that *Oceanic, Beuchat* and *Seeman Sub* computers could change to the correct water type automatically but only at altitude and so could not change to freshwater (FW) if in a FW environment at low altitude (it was assumed that this was a simple assumption of FW only at altitude; salinity/conductivity was not being measured).

3.3.3. Data retrieval

It was an entry condition to the present study that all of the computers had to be capable

Table 3: Minimum user settings, automatic detection, the ability to integrate with the cylinder and download methodologies of 47 models of downloadable diving decompression computers as retrieved from the relevant technical manuals. Spaces indicate where no information was found or was unclear

Brand	Model	Gases	No. of gas mixes	User settings			Cylinder integration	Download method	Reference
				sw/fw	Conser-vatism	Altitude			
Uwatec	Galileo Sol	Air; Nitrox	3	Yes	Yes	Auto	Yes	Infrared	Scubapro-Uwatec (n.d.-a)
Uwatec	Galileo Terra	Air; Nitrox	1	Yes	Yes	Auto	No	Infrared	Scubapro-Uwatec (n.d.-b)
Uwatec	Smart Tec	Air; Nitrox	3	No	Yes	Auto	Yes	Infrared	Scubapro-Uwatec (n.d.-c)
Uwatec	Smart Com	Air; Nitrox	1	No	Yes	Auto	Yes	Infrared	Scubapro-Uwatec (n.d.-d)
Uwatec	Aladin Pro Ultra	Air; Nitrox	1	No		Auto	No	plug in	Scubapro-Uwatec (n.d.-e)
Uwatec	Aladin Tec 2 G	Air; Nitrox	2	Yes	Yes	Auto	No	Infrared	Scubapro-Uwatec (n.d.-f)
Uwatec	Aladin Prime	Air; Nitrox	1	No	No	Auto	No	Infrared	Scubapro-Uwatec (n.d.-g)
Uwatec	Aladin One	Air; Nitrox	1	No	No	Auto	No	Infrared	Scubapro-Uwatec (n.d.-h)
Scubapro	Xtender	Air; Nitrox	1	No	Yes	Auto	No	plug in	Scubapro-Uwatec (n.d.-i)
Mares	Nemo	Air; Nitrox	1	Yes	Yes	Yes	No	Infrared	Mares (2005)
Mares	Nemo Sport	Air; Nitrox	1		Yes	Auto	No	plug in	Mares (2007)
Mares	Nemo Air	Air; Nitrox	1	Yes	Yes	Yes	Yes	plug in	Mares (2008a)
Mares	Nemo Excel	Air; Nitrox	1	Yes	Yes	Yes	No	Infrared	Mares (2008b)
Mares	Nemo Wide	Air; Nitrox	3	Yes	Yes	Yes	No	plug in	Mares (2008c)
Mares	Puck wrist	Air; Nitrox	1	Yes	Yes	Yes	No	plug in	Mares (2008d)
Mares	Puck Air	Air; Nitrox	1	Yes	Yes	Yes	Yes	plug in	Mares (2008e)
Suunto	D9	Air; Nitrox	3	No	Yes	Yes	Yes	plug in	Suunto (2006b)
Suunto	D6	Air; Nitrox	2	No	Yes	Yes	No	plug in	Suunto (2006c)
Suunto	D4	Air; Nitrox	1	No	Yes	Yes	No	plug in	Suunto (2007b)
Suunto	Stinger	Air; Nitrox	1	No	Yes	Yes	No	plug in	Suunto (2006d)
Suunto	Spyder	Air	1	No	Yes	Yes	No	plug in	Suunto (n.d.-b)
Suunto	Vytec DS	Air; Nitrox	3	No	Yes	Yes	Yes	plug in	Suunto (2005)
Suunto	Cobra	Air; Nitrox	1	No	Yes	Yes	Yes	plug in	Suunto (2006a)
Suunto	Cobra 2	Air; Nitrox	2	No	Yes	Yes	Yes	plug in	Suunto (2007c)
Suunto	Cobra 3	Air ; Nitrox	2	No	Yes	Yes	Yes	plug in	Suunto (2008a)
Suunto	Vyper	Air; Nitrox	1	No	Yes	Yes	No	plug in	Suunto (2006e)
Suunto	Vyper 2	Air; Nitrox	2	No	Yes	Yes	No	plug in	Suunto (2007a)
Suunto	Vyper Air	Air; Nitrox	2	No	Yes	Yes	Yes	plug in	Suunto (2008b)
Tusa	DC Sapience	Air; Nitrox	1	Yes	Yes	Auto	No	plug in	Tusa (2004b)
Tusa	DC Hunter	Air; Nitrox	2	Yes	Yes	Auto	No	plug in	Tusa (2004a)
Oceanic	Veo 250	Air; Nitrox	1	No		Auto	No	plug in	Oceanic (2002b)
Oceanic	VT 3	Air; Nitrox	3	No	Yes	Auto	Yes	plug in	Oceanic (2006)
Oceanic	Pro Plus 2	Air; Nitrox	1		Yes	Auto	Yes	plug in	Oceanic (2002a)
Oceanic	Atom 2	Air; Nitrox	3		Yes	Auto	Yes	plug in	Oceanic (2005)
Oceanic	Datamask Hud	Air; Nitrox	1	No	Yes	Auto	Yes	plug in	Oceanic (2007)
AP Valves	Buddy Nexus	Air; Nitrox	2	Yes	Yes	Yes	No	Infrared	AP Valves (2003)
Citizen	Cyber Aqualand NX	Air; Nitrox	1	No		Auto	No	plug in	Citizen (n.d.)
Cressi Sub	Archimede 2	Air; Nitrox	2	No	Yes	Auto	No	plug in	Cressi Sub (n.d.-a.)
Cressi Sub	Edy II	Air; Nitrox	1	No	Yes	Auto	No	plug in	Cressi Sub (n.d.-b.)
Beauchat	Voyager	Air; Nitrox	1	No	No	Auto	No	plug in	Beuchat (2004)
Apeks	Quantum	Air; Nitrox	2	Yes	Yes	Auto	No	plug in	Apeks (2003a)
Apeks	Pulse	Air; Nitrox	2	Yes	Yes	Auto	No	plug in	Apeks (2003b)
VR Technology	VRX	Air; Nitrox; Trimix	10	No	Yes	Auto	No	plug in	VR Technology (2009)
VR Technology	VR 3	Air; Nitrox; Trimix	10	No	Yes	Auto	No	plug in	VR Technology (2009)
Seeman	XP5	Air; Nitrox	1	No	Yes	Auto	No	plug in	Seeman (2004)
Uemis	SDA	Air; Nitrox;	3	Yes	Yes	Auto	Yes	plug in	Uemis (2009)

of storing dive data that could be downloaded. As is shown in Table 3, there was no standard when it came to connecting dive computers to PCs for downloading purposes. Some models used cradles with connection points that link to wet contacts; others used cables that plugged into the dive computer. The *Uwatec* Aladin Pro Ultra downloaded *via* a storage device known as a *Data Mouse* which could also be used independently of a PC to store dive information.

Another data transfer method employed infrared and a number of *Uwatec* and *Mares* dive computers as well as the *Buddy* Nexus, used this method (Table 3). Data transfer often depended on accurate positioning of the infrared device and in some models it was not always as efficient as using a direct physical connection.

All the computer models in this present study successfully downloaded dive information to a desk-top PC. All associated software packages gave, as a basic minimum, a PC-based graphic representation of a dive profile as well as important information such as the maximum depth reached, the water temperature, any safety or decompression stops made or violated and were mostly relatively straightforward to use. The exception was the software supplied for the *Buddy* Nexus computer which was delivered on a 1.44″ floppy disk and only functions on PCs running operating systems of *Windows 2000* or earlier versions (the purchase was made in 2009). In addition, the PC operating speed had to be reduced to enable the software to function.

3.3.4. Additional features

Diving computer technology has developed to such an extent that newer models incorporate an increasingly wide range of additional features. Many of these features involve data entry by the user while the computer is connected to a PC and is not reviewed here as the list is exhaustive and there is little commonality. Instead, the present review examines only the additional features that are measuring and recording data during the actual dive.

The *Uwatec* Galileo Sol computer can connect to a heart rate monitor which sends information to the computer. This data on the workload experienced by a diver is used to modify the decompression modelling as well as providing a download record. The *Uemis* SDA also incorporated workload information to adjust the dive length or decompression obligations through monitoring gas consumption patterns. It also used a skin cooling model based on the water temperature as did the *Uwatec* computers in this review (Scubapro-Uwatec, 2008).

A significant number of the computer models assessed had some form of gas integration whereby the diver's cylinder pressure could be monitored by the computer *via* a wireless pressure transponder located typically in a high pressure port on the regulator first stage (Table 3). As well as monitoring cylinder contents, the information could also be used to calculate the remaining dive time, workload, *etc.* Instead of wireless integration, some computers, such as the *Mares* Nemo Air and Puck Air, the *Suunto* Cobra series and the *Oceanic* Pro Plus II, were connected to the cylinder by a high pressure hose.

4. Discussion

The present study is a review of the basic technical parameters available in 47 models of dive decompression computers currently available for purchase in the UK. The review was based on the technical information that was either internet-based or supplied with the individual computer model. There were examples where the technical capacity of the computer described in the literature could not be physically replicated on the actual model, for example setting conservatism levels on the *Uwatec* Aladin Prime and the dive capacity of the Galileo Sol and Terra models. A number of claims made in the literature were not tested in this study and should be subject to future evaluation.

The volume and detail of data sets that could be recorded, stored and downloaded from computers that, in some cases, are little bigger than a standard wrist watch was impressive. However, there is an underlying design and engineering context that limits the volume and type of data that can be stored and displayed at what resolution, and what impacts storage capacity and the volume of data manipulation has on the overall computational capacity of the unit. Ultimately, compromises are probably made over what is measured, when and how in order for the decompression algorithms to function optimally, and what and how this information is filtered to present stored and displayed information to the user. There is significant variability across the models employed in this study in how the data are recorded and displayed and it is important that all users of the data stored, whether they are involved in sports, technical, commercial or scientific diving, or accident investigators, are aware of specifications and limitations of what is being made available to them. That is, of course, if the data can be retrieved and although at the outset of modern dive computer development there were requests for uniformity of design (Lang and Hamilton, 1988) this has not occurred and their download methods range in their approach and ease of use.

The development of dive computers in modern times has come in a small number of very distinct phases that have often been linked with concomitant advances in general micro-processor development (e.g. advances in storage capacity, processing speed and volume, battery performance, sensor miniaturisation). The present phase of dive computer evolution is distinctive through the marked increase in the number and types of dive computer available, the measured and displayed parameters and the diversification in methods of decompression computation and diving theory. It is possible that this evolution will produce unwelcome outcomes associated with misunderstanding how the computers work (e.g. Sayer et al., 2008).

How this increasing diversity relates to actual dive management practices has yet to be tested but must be based on a clear understanding of how the computer is functioning.

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