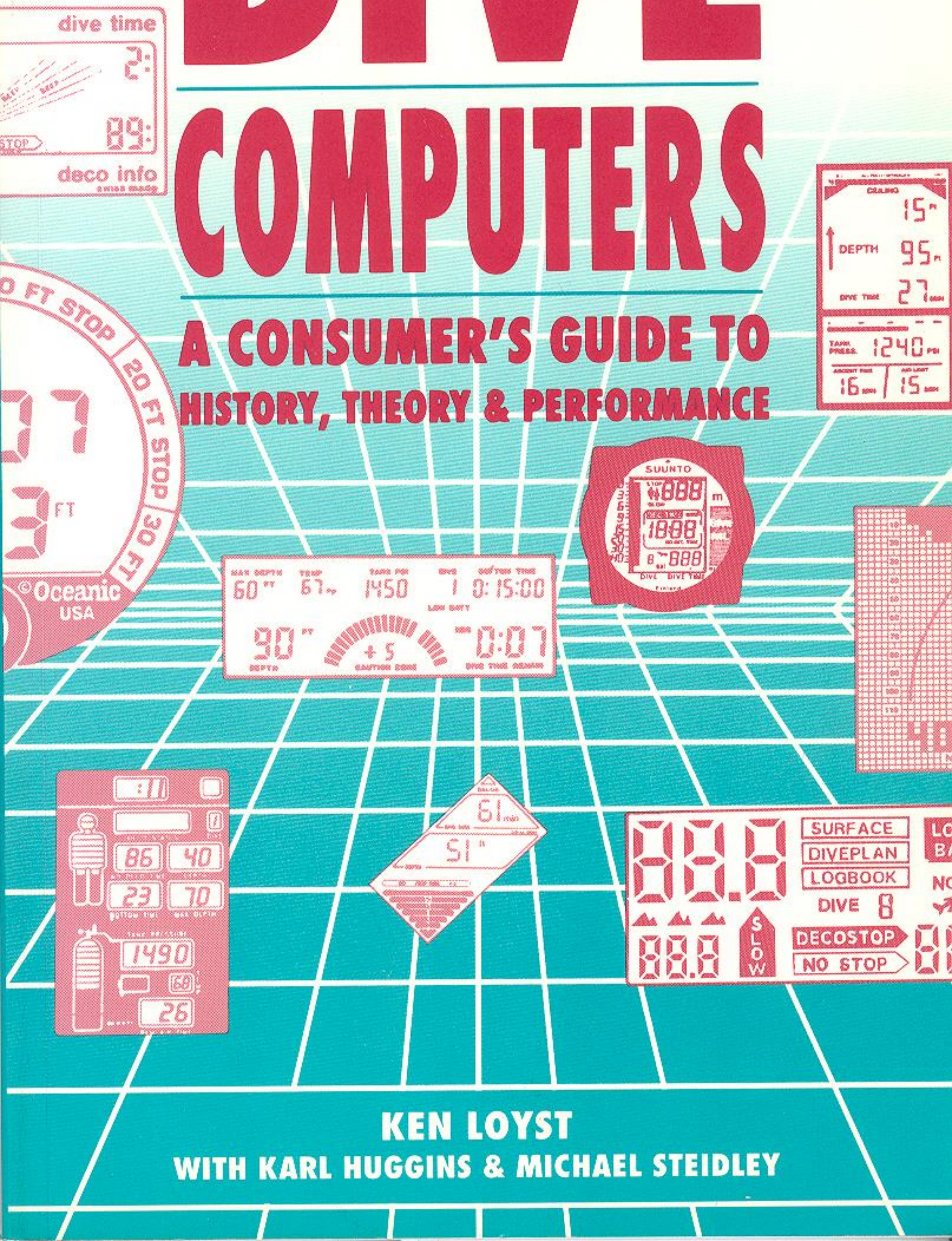
DIVE COMPUTERS

A CONSUMER'S GUIDE TO HISTORY, THEORY & PERFORMANCE



KEN LOYST

WITH KARL HUGGINS & MICHAEL STEIDLEY

Dive Computers

A Consumer's Guide to History, Theory, and Performance

1991

by Ken Loyst
with Karl Huggins and Michael Steidley

Table of Contents

Acknowledgements

A project as involved as this dive computer information and comparison book requires the help of many people. We must thank many manufacturers and distributors for providing technical information through their helpful employees. These people include Doug Toth of Scubapro, Scott Mastrangelo of Parkway, Peter Radsliff of Oceanic, Mark Walsh of Dacor, James Fulton and Paul Heinmiller of Orca, Francois de Toledo of Beuchat, Dan Babcock of Sherwood, Andrea Greatrake and Brian Miller of U.S. Divers, and Ron Coley for providing information for SeaQuest and Tekna products. Also, Bruce Wienke of Los Alamos Laboratories for his useful input and comments.

A special thanks goes to Danny Rossi who provided many hours of his time helping us compile data contained in the comparison charts and for his valuable contribution of our High Altitude chapter.

Instrumental in helping with layout, design, and editing was Denise Winslett. Robert von Maier and Jolee Brunton spent days of their time editing the manuscript.

And, the support of a number of people as data collectors and members of our test dive team must be mentioned: Pat van Mullen, Jolee Brunton, Jens Rubschlager, Chip Alexander, Hobie Hawthorne, and Sally McGillicuddy.

Our sincerest thanks to everyone involved.

Ken Loyst
Karl E. Huggins
Michael Steidley

Introduction

In the last decade, there have been considerable innovations in diving equipment. Manufacturers are producing equipment that is safer, more comfortable, and color coordinated. These innovations are making diving more enjoyable and less complicated. During the past four years there has been a plethora of new dive instrumentation, including computers, introduced to the diving public.

The purpose of gauges, meters, and instrumentation is to provide the user with information. These tools, being the implements of information, are only as good as the person interpreting them, and, of course, only as good as the accuracy of the instrument itself. If common sense is not applied to the reading of an instrument, then it is of no value to the user. An example would be watching your fuel gauge until it showed "E" *(or empty)* and not believing you are out of gas until your vehicle coasts to a stop. The gauge did not serve as a useful tool *(providing that it was accurate)*, because the information was not used to prevent the out of gas situation. In an aircraft, this example could prove to be disastrous for the pilot, passengers, and innocent others on the ground. In diving, it could prove to be at least a nuisance, and at worst fatal for the interpreter.

Sport divers constantly track instruments, such as pressure gauges, depth gauges, and bottom timers, which provide useful information to make the dive experience a safe and enjoyable one. The depth and bottom time data are used to calculate the absorption of nitrogen with a set of dive tables. These calculations can become complicated when figuring multi-level profiles and repetitive dives. They are only as accurate as the data recorded and the computations performed by the user. If a mistake is made on the first dive of a series, then every subsequent dive will carry and amplify this mistake.

Dive computers have made diving much easier and calculations of dives more accurate and convenient *(see History of Dive Computers, Chapter 1)* Dive computers have brought divers a new dimension in diving freedom. Dive computers are actually minicomputers that interpret the depth and duration of a dive *(or dives)* and calculate nitrogen exchanges based on mathematical models similar to the ones from which the U.S. Navy Repetitive Dive Tables were developed. These instruments are extremely accurate in determining depth (±1') and tracking elapsed time. Calculations are continually made every 1 or 3 seconds *(depending on the computer)* and the display is updated to give the diver new data showing the safe remaining time, ascent rates, decompression time and stops, etc., according to the model in use. The computers do not miscalculate the information provided. They can, however, be used improperly. The improper use of a dive computer means that the data retrieved from it is invalid *(See Guidelines For Using Dive Computers, Chapter 5)*. Dive computers can also be an enhancement to diver safety as an aid in avoiding decompression sickness if used properly.

The benefit from the dive computers comes from the fact that they are dynamic or "alive"; actually diving with a diver. As a consequence, the computer continuously monitors a diver's status *(theoretical nitrogen in-gassing and out-gassing)* with regard to time and depth. A set of dive tables, in contrast, is a rigid device that helps to calculate this same information based solely on the maximum depth reached and the length of time spent underwater.

Divers rarely go to a single depth and stay there for their entire dive. As a result, a diver using dive tables is penalized with having to use the maximum depth for dive table calculations. In reality a diver may have spent only a small portion of the dive at the maximum depth and the majority of the dive may have been spent at shallower depths where the nitrogen uptake in the body may have been much lower. The net result is that divers using a set of dive tables must spend less time underwater than if they had a computer continuously monitoring the theoretical nitrogen in-gassing and out-gassing.

The nature of electronic technology is so volatile, it is difficult for consumers to stay abreast of rapidly changing products. Currently there are a number of dive computers on the market, and each of them have their own unique benefits and features. In some cases, the theoretical basis on which these computers have been developed are different. These categories may be summarized as **Table Based or Model Based** dive computers. The Table Based dive computers will not be covered in this book, however, each of the Model Based dive computers *(five types in all)* will be discussed. One of these types of computers may actually serve a certain type of diver's needs better than another. The decision as to which computer best fits a diver's particular needs is easier to make when based on all the facts about the development and features of the computer.

About This Book

The purpose of this text is to help educate divers to use dive computers safely, and to aid in making an intelligent decision as to which dive computer would best fit their needs. This goal will be accomplished by providing information on computer working theories, half-times, types, and comparisons of features. Topics about the inter-relationship between decompression theory and practical applications of using a dive computer will be dealt with to help enhance diver awareness.

The text is divided into ten chapters. Each chapter is designed to stand alone so that a diver may skip chapters and go directly to sections that may be of more interest. We hope that you will start at page 1 and read the entire book. There are many important topics covered in each chapter. Pay special attention to Chapter 5 which contains **Guidelines For Using Dive Computers**. This information is important to every diver using a dive computer.

Throughout the book new or special terms are found in **bold** letters. Each of these terms are found in the glossary at the end of the book. The glossary is set-up as an easy reference guide that defines terms used in this text.

For those of us who love the underwater world, the advent of dive computers has greatly enhanced our recreation. Using computer assisted multi-level diving techniques will allow divers to spend more time underwater. It is important to remember, however, that diving computers are a tool that must be both understood and used properly. Take the time to understand decompression theory and the theory behind the computers so that you may better understand their strengths and limitations. Strive to understand the proper and safe use of these computers and you can enhance your diving safety.

This book is written for all of you underwater enthusiasts who want to spend more time below the surface and yet are concerned about diving safety... See you underwater!

Chapter 1

History and Development of Dive Computers

In the last decade, there have been considerable innovations in diving equipment. The development of dive computers has been a striking example of one area of innovation. In July 1988, *Discover Diving* Magazine began a four part series comparing and explaining dive computers. Subsequently, in January 1989, the first book on dive computers, ***Diving With Dive Computers***, was published, based on that four part series, and augmented by the culmination of hundreds of hours of research and comparative diving. Because the nature of this electronic technology is so volatile, it is difficult for consumers to stay abreast of rapidly changing products.

The diving industry has developed a plethora of dive computers. Since our original book on computer comparisons two years ago, the number of computers that a diver could purchase has grown from 9 to today's 24 available units. And the near future will bring us even more choices.

These dive computers, or electronic dive monitors, have brought divers a whole new dimension in diving freedom with extended underwater times. The dive computers calculate a diver's theoretical nitrogen uptake and release based on mathematical models similar to the one from which the U.S. Navy Dive Tables were developed. The development of dive monitors from an historical standpoint is quite interesting.

My dear Karl,

(and i really hate to write this!) once and for all:
the guy's name is A.A.Bühlmann (note the „ü"!. „A.A." is for: Albert Alois)

He designated his(*) decompression algorithms as:

→ **ZH-L$_{12}$** (note the position of the hyphen and the subscript!)
→ **ZH-L16** (note the position of the hyphen and no (!) subscript)

And, for all those who think the ZH-L$_{12}$ is a 12 compartment-model: it is not!
It is a 16 compartment model for mixed gas, the „12" designates the number of different coefficent (a- & b-) pairs for Nitrogen **&** Helium.

And, by the way, the „L" is not for „limits" or for german „Luft" or the like!
It is just **for „L" like „LINEAR"!**
Simply, because the equation for the allowed / tolerated inertgas partialpressures per compartment, that is: per half-time & a-/b combination, is a simple, **linear** equation.

All of the above could be easily checked in the original papers / books from Albert Alois:

[4] Bühlmann, A.A. (1983): Dekompression - Dekompressionskrankheit, Springer, ISBN: 3-540-12514-0

[4a] Bühlmann, A. A. (1990): Tauchmedizin (Barotrauma, Gasembolie, Dekompression, Dekompressionskrankheit),
zweite Auflage, Springer, ISBN: 3-540-52533-5

[5] Bühlmann, A. A. (1993): Tauchmedizin (Barotrauma, Gasembolie, Dekompression, Dekompressionskrankheit),
dritte Auflage, Springer, 1993, ISBN: 3-540-55581-1

[5a] Bühlmann, A. A. (1995): Tauchmedizin (Barotrauma, Gasembolie, Dekompression, Dekompressionskrankheit,
Dekompressionscomputer), vierte Auflage, Springer, 1993, ISBN: 3-540-58970-8

[65] Bühlmann, Albert A., Völlm, Ernst B. (Mitarbeiter), Nussberger, P. (2002): Tauchmedizin, 5. Auflage, Springer, ISBN: 3-540-42979-4

(*) means, that there were many, many co-workers (a couple of them whom i know), but never mentioned or appreciated in the above cited sources. Just to name a few of them, to set the records, at least partially, straight:
Hannes Keller, Benno Schenk, Jürgen Herrmann, Maxe Hahn, Ernie Völlm, Beat Müller, …

And, just to set some other records straight, at least concerning the RDP / PADI DSAT Table, which you mentioned on p.54 & 57, with only 8 compartments: this is FALSE, completely! **PADI DSAT© / RDP® uses 14 compartments from 5 to 480 min!**

This, as well, could have been checked in the real, original publication:
[3] Hamilton, Rogers, Powell, Vann (1995): The DSAT Recreational Dive Planner: Development and validation of no-stop decompression
procedures for recreational diving, 28 Februar 1994 (DSAT Script), ISBN: -

brgds

ALBI

אלבי

A Brief History of Dive Computers

The sudden appearance of a multitude of electronic dive monitors in recent years tends to make one think that these devices have come from the cutting edge of diving technology. In reality, the concept of a device that can model a diver's nitrogen absorption and elimination during a dive is surprisingly old. Decompression computing devices originated with mechanical and electrical analog computers. Older concepts and theories have of course been upgraded and revised with development of modern technology, but the ideas and principles are actually more than three decades old. Modern advances have led to microprocessor-based digital computers. Due to recent advances in affordable electronic microprocessor technology, and the advent of reliable inexpensive pressure transducers, electronic dive computers have become a reality.

The Need for a Decompression Monitor

The introduction of SCUBA (Self-Contained Underwater Breathing Apparatus) during World War II radically changed the notion of tethered deep sea diving. Surface-supplied hardhat divers would spend their entire dive at one depth. Surface tenders were responsible for computing and executing the decompression requirements of the hardhat diver. The new free-swimming scuba divers were without tether. These scuba divers were separated from surface contact and had to be responsible for their own decompression information. Thus, a need evolved for a mechanism to determine decompression status underwater with the advent of scuba.

Historically speaking, the need for a device to help divers to determine decompression status and prevent decompression sickness was recognized in the early 1950's. During this period, the U.S. Navy formed a committee for Undersea Warfare and Underwater Swimmers. The purpose of this committee was to identify improvements required in diving equipment to fit scuba operations. One of the topics that this committee discussed at a meeting at Scripps Institute of Oceanography in 1951 was how to control decompression sickness for a non-tethered free swimming scuba diver.

In 1953, this committee issued a report. The following is a quote from this report *(Groves and Monk, 1953)*:

> *"In ordinary diving [hard hat], the tender aboard the ship keeps a log of the depth-time history of the dive and then computes the decompression requirements from a table. For a diver using self contained equipment, three possibilities present themselves: (a) the diver keeps a log of depth and time and then computes the decompression requirement underwater (this requires a depth gauge, watch, and skill); (b) the diver follows a prearranged schedule (both limiting and boring); (c) by guess and by God. None of these alternatives are entirely satisfactory."*

The report went on to offer a preliminary design for a decompression device that would be diver-carried. It was a two-tissue-group pneumatic analog computer which simulated nitrogen uptake and elimination. The following statement from the same report shows not only the perceived advantage of such a device, it represents what the diving industry has accomplished over 35 years later:

> *"The gauge automatically takes into account the depth-time history of the entire dive. The resulting continuous "optimum ascent" should be somewhat more efficient than the usual step-wise ascent, the latter being used only because of its greater simplicity of presentation in tabular form."*

and:

> *"There are two other situations for which the gauge is conceivably an improvement over the table. For repeated dives the gauge automatically takes into account the residual elevation of nitrogen pressure in the body from the proceeding dives. (Divers are known to be more subject to bends on subsequent dives.) In the case of an emergency ascent, such as may be required by an exhaustion of breathing air, the gauge gives some indication of the desirable re-compression procedure."*

In addition, this report contained the design for the "Ultimate Gauge" which was an electrical analog computer. This superior device would include both decompression and air consumption data, giving the diver the required information to implement a decompression procedure while knowing the remaining air supply was sufficient.

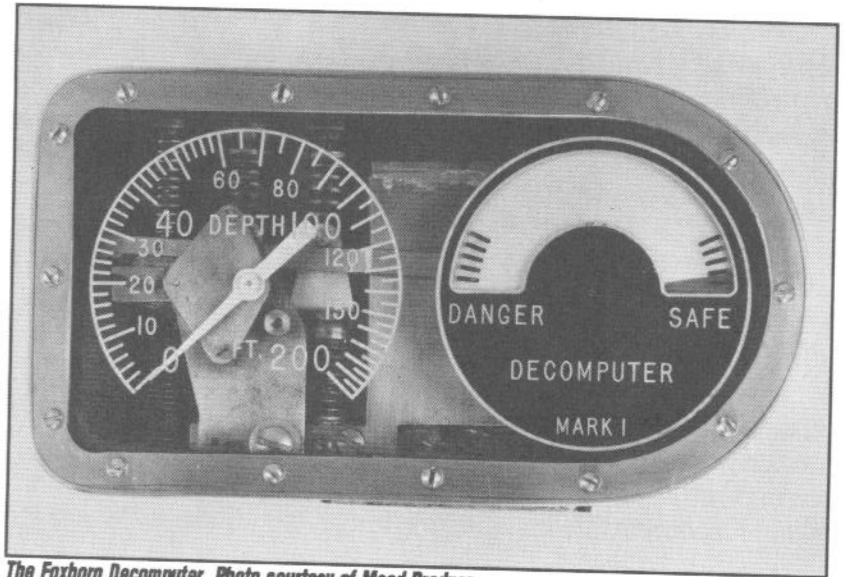
Three years later, a quote from the Naval Experimental Diving Unit (NEDU) again indicated that there was a need for some type of decompression device. The quote *(Searle, 1956)* pointed out:

> *"With the ever widening fields of both civilian and military free-swimming and diving using self-contained breathing apparatus, and particularly when diving is untended from the surface, there arises a need for a small portable indicating apparatus to be used to indicate proper decompression in ascent."*

From these quotes it is obvious that the need for a dive monitoring device was recognized more than three decades ago, and what followed developed into the predecessors of today's dive computers.

Foxboro Decomputer

From the recognition of the need for a decompression monitoring device, it wasn't long until the first model was realized. Foxboro submitted the first decompression meter to the Naval Experimental Diving Unit (NEDU) in late 1955. This first decompression monitor was called the **Foxboro Decomputer Mark I** and it was a two tissue pneumatic device based on the design from the Groves and Monk report (1953). This dive computer had two half-time compartments of 40 and 75 minutes. The computer used a combination of bellows, springs, and porous resistors to simulate nitrogen absorption and elimination from the two compartments.



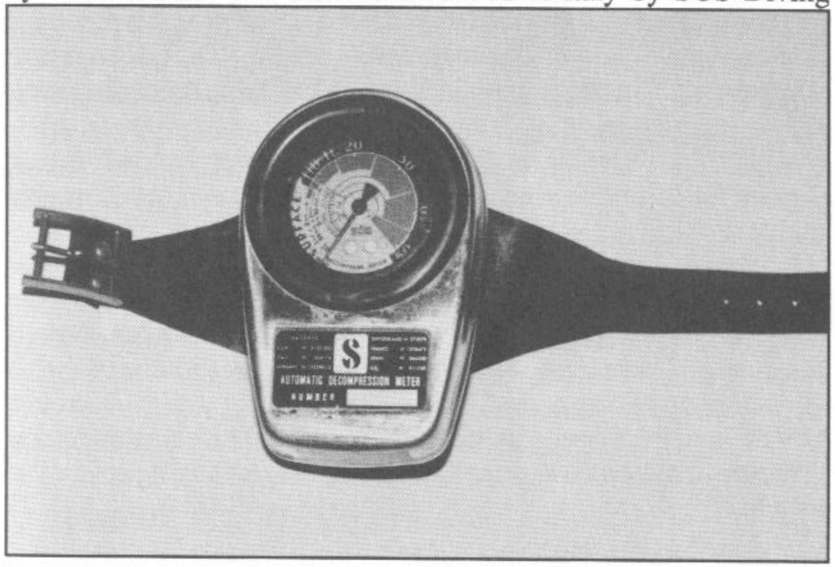
The Foxboro Decomputer Photo courtesy of Mead Brodner

Evaluation by the NEDU concluded it was unacceptable because of inconsistent readings within the U.S. Navy Dive Table decompression ranges. The device was returned to Foxboro by the Naval Experimental Diving Unit for modification and re-evaluation. Unfortunately, Foxboro never modified or re-submitted the Mark I to the Navy.

The US Navy rejected the idea and feasibility of a decompression computer and accepted option (a) as listed in the Groves and Monk report of 1953, using a depth gauge, watch, dive tables, and wit. About the same time, the U.S. Navy published a new set of air no-decompression tables and repetitive dive tables in 1957.

The SOS Meter

In 1959, the first and probably most well known decompression device became available. This first commercially produced device was called the **SOS Decompression Meter**. The SOS was designed by Carlo Alinari and was manufactured in Italy by SOS Diving



The SOS Meter

Equipment Limited. The SOS Meter is still manufactured and available in Europe. The SOS Meter was first introduced to the United States by Healthways who began distribution in 1961. In 1963 Scubapro acquired the distribution rights and became the sole U.S. distributor. This device is a one compartment, pneumatic device which is supposed to be an analog to the average body tissue.

Early Dive Computers

The **TRACOR** Electrical Analog Computer was developed in 1963 by Texas Research Associates Inc. This device had a 10 section ladder network of series resistors and parallel capacitors designed to simulate nitrogen diffusion within the body. An evaluation by NEDU proved the **TRACOR** to be undependable because *"Temperature dependency of the instrument was excessive, particularly for cold exposures"*... resulting in "*...widely varying decompression requirements for the same dive schedule.*"

In the late 1960's the first thoroughly tested and successful decompression computer was developed by the Defense and Civil Institute of Environmental Medicine (DCIEM). This DCIEM Analog Series **Mark VS** was very good, but, unfortunately, due to extensive maintenance and calibration requirements it was too expensive to be a viable product for sport divers.

Even General Electric (1973) tried their hand at developing a dive computer, the **GE Decompression Meter**. The GE computer was successful in that it proved the concept of using semi-permeable silicon membranes and a four-chamber mechanism with compartments of 24, 39, 90, and 144 minute half-times. Initial GE tests showed the computer to be viable, but the product was never brought to market.

Farallon Industries (currently Oceanic) took advantage of the semi-permeable membrane technology to produce an analog decompression meter in 1975 that was called the **Decomputer**. Scripps Institute of Oceanography tested the computer and found that it *"failed to approximate the U.S. Navy air decompression limits and tables."* and the Royal Australian Navy found the Decomputer to be *"too permissive and it developed too much mechanical deterioration with use."*

Pressure Transducers

Presently, modern electronic technology has made it possible to develop digital dive monitors that use pressure transducers and microchips. These electronic devices are actually pressure actuated mini-computers that use algorithms or mathematical formulas to calculate nitrogen uptake and release based upon theoretical decompression models *(Refer to Chapter 6 for an overview of the components and how a dive computer works).*

The real advance that allowed the dive computers to become viable was low cost temperature-stable pressure transducers and low cost microprocessors with low power drain.

Digital Dive Computers

In the mid-1970s, DCIEM developed their XDC digital dive computer series based on microprocessor technology. These computers were programmed with the Kidd-Stubbs model developed for the successful Mark VS Analog computer. The first two computers were surface based, but the XDC-3 (also called the Cyberdiver) was the first microprocessor-based, diver carried, dive computer. The major problem with the XDC-3 was its large power requirements which required battery changes every four hours.

In 1978–79, the Dacor Corporation of Illinois produced a prototype electronic dive computer called the **DDC**, which stood for Dacor Dive Computer. The **DDC** was never mass produced because of complications in chip acquisitions *(the toy industry bought all of them for the new electronic toys)*. Additionally, the LED display consumed too much energy from the power source during 12 hour surface intervals and the special batteries designed for the device were difficult to acquire.

Two additional dive computers came out of Canada at the beginning of the 1980's. These were the Cyberdiver II and the Cyberdiver III. The Cyberdiver II was a device that would read the U.S. Navy Tables. The Cyberdiver III used the Kidd-Stubbs model to calculate decompression status. The Cyberdivers attained some acceptance in the recreational diving community in the few years before the dive computer explosion started in 1983.

First Sport Diving Models

The first truly successful commercially available dive computers were the Orca **Edge** and the **DecoBrain I** that were both introduced in 1983. The Edge was a multi-level computer which used a Haldanean Model based on Spencer's "silent bubble" work, whereas the DecoBrain I was a Table Based multi-level decompression device that read the Swiss Tables. *(For a comparison of theoretical models see Chapter 3)*

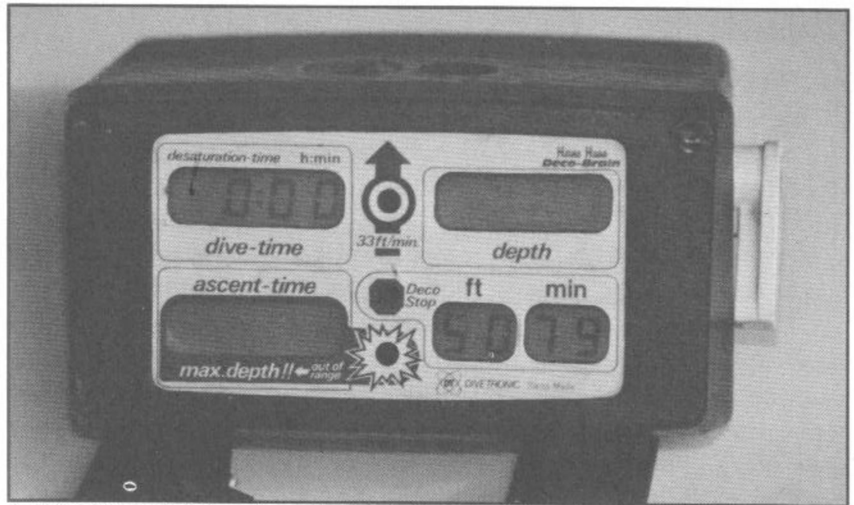
The year 1983 also marked a first time ever cooperative effort between two major scuba manufacturers to co-develop a product. Oceanic USA and U.S. Divers Company combined forces in a $1.5 million research effort. The actual research and development which took several years was carried out by Pelagic Pressure Systems which is located in San Leandro, California. The outcome of this research project resulted in two separate dive computers which were named the Oceanic **DataMaster II** and the U.S. Divers **Data Scan 2** *(introduced in 1987)*. These dive computers were a radical departure from previous designs because they integrated both a no-decompression computer and an air consumption computer.

By 1985, the **DecoBrain II** was released with an upgraded software program. The manufacturer and distributor, Divetronic AG, based this dive computer on a 16 half-time compartment Swiss Model with half-time ranges from 4 to 635 minutes. This was the first reliable working dive computer designed for altitude capabilities up to 4500 meters above sea level. The model (ZHL-12) was developed by Dr. A. A. Buhlmann. After cases of Type 1 decompression sickness (DCS) reported by the users *(mostly skin bends)*, the program was shifted from the P2-1 to the P2-2 and later to the safer P2-3 software version. Divetronic AG received no reports of DCS with several thousand working units of their P2-3 dive computer, however, due to major leakage problems, production was discontinued in 1987 *(Not as many P2-3 units were shipped compared to P2-2 units)*.

1987 Models

In 1987 Orca Industries developed the **SkinnyDipper**, which was another milestone in computer development. The SkinnyDipper was both more user friendly and more economically priced than its predecessor, the Edge. The SkinnyDipper was the first American dive computer to feature a red LED warning light in addition to its LCD screen. The major difference between the SkinnyDipper and the Edge was that the Edge was designed to be a no-decompression dive computer that provided full decompression information whereas the SkinnyDipper was designed as a no-decompression dive computer.

Suunto developed two new computers in 1987. The Suunto computers are distributed in the United States by SeaQuest. The Suunto **SME-ML** is a Model Based multi-level dive computer and the **SME-USN** is a Table Based dive computer that utilizes the U.S. Navy Tables. The SME-USN is very conservative and limiting. The SME-ML, on the other hand, is a multi-level device that is comparable to the other multi-level devices on the market. Both of the Suunto computers have a unique dive recall feature. This dive recall feature allows a diver to recall an entire dive profile showing the



Production of the DecoBrain II, manufactured by Divetronic AG of Switzerland, was discontinued in 1987.

diver's maximum depth every 3 minutes. These dive computers were the only computers on the market that had this type of dive profile recall capability, until the recent Orca Delphi, Suunto Solution, and Scubapro DiveVu in 1990 and 1991.

Oceanic introduced their **DataMaster II** model dive computer *(and U.S. Divers their **Data Scan 2**)* which worked on John Lewis' algorithm using the U.S. Navy Model with lower M-Values. These were the first dive computers with an air pressure gauge incorporated into the display.

Also in 1987, Uwatec of Switzerland introduced the **Aladin** and Beuchat brought the distribution of the Aladin to the American diving market initially as the **G.U.I.D.E.**, while Parkway marketed the same computer as the **Black Fox**. The Aladin was a compact computer that was popular among divers because of its economical price, however, its major drawback was that it did not scroll no-decompression data between dives. Uwatec continued to market the Aladin in Europe and Beuchat subsequently dropped the G.U.I.D.E. packaging in the U.S. and called their dive computer the Aladin.

1988 Models

The 1988 Diving Equipment Manufacturers Association (DEMA) Trade Show in New Orleans brought Dacor's new computer, the **Micro Brain**, into the market place. The Dacor Micro Brain was a Swiss Model multi-level dive computer. The Dacor model is

1951	*Scripps meeting to control decompression sickness of non-tethered scuba divers*
1953	Groves Monk report to the Navy about free swimming scuba divers
1956	Foxboro **Decomputer Mark I**
1957	U.S. Navy Air No-Decompression Tables re-designed
1959	**SOS Decompression Meter**
1963	**TRACOR** Electronic Analog Computer
1968	DCIEM Analog Series **Mark VS**
1973	**GE Dive Computer**
1975	**Farallon Decomputer** DCIEM **XDC** series
1978	**Dacor Dive Computer** (DDC) **Cyber Diver I** & **II**
1983	**Deco Brain I** Orca **Edge** (first successful commericially available dive computer)
1987	Orca **SkinnyDipper** Suunto **SME-ML / UNN** Beuchat **Aladin G.U.I.D.E.** Oceanic **DataMaster II** U.S. Divers **Data Scan 2**
1988	Dacor **Micro Brain** Sherwood **Sigmatech**
1989	Orca **SkinnyDipper Mark II** Oceanic **DataMaster Sport** Oceanic **DataMax Sport** U.S. Divers **Data Scan 3** U.S. Divers **Monter I & II** Suunto **SME-ML R1** Dacor **Micro Brain Pro Plus** Beuchat **Aladin Pro**
1990	Orca **Delphi** & **Delphi Pro** Sherwood **Source** Tekna **Computek** Oceanic **DataMaster Sport/S** Beuchat **Aladin Sport** Parkway **Legend** Scubapro **NC-11** & **DC-11**
1991	Suunto **Solution** Scubapro **Dive Vu**

referred to as the Buhlmann-Hahn P-3 model adapted to be more conservative than the Spencer No-D Limits Models. The Micro Brain was designed with altitude diving capabilities. The Micro Brain also has a dive log memory recall, which gives time and depth for up to 6 dives within the previous 48 hours.

Another addition to the dive computer market in 1988 was the Sherwood **Sigmatech**. The Sigmatech was actually a SkinnyDipper that was packaged into a console with a submersible pressure gauge.

1989 — The New Generation

Several of the computer manufacturers made revisions in 1989 to their existing dive computers increasing either the number of features or the capabilities. Key revisions came from Suunto, Orca, Uwatec, Oceanic, and U.S. Divers. Orca also introduced a completely new dive computer at the end of 1989.

Suunto introduced a revised version of the Suunto SME-ML called the **R1** (distributed in the U.S. by SeaQuest). The revisions included a modification in the

manner that the dive profile recall was displayed as well as the addition of a digital maximum depth display following the dive.

Orca had a number of problems with flooding through the battery compartment in their popular SkinnyDipper computer. This was for the most part because of a poorly designed battery compartment door. Orca fixed the problem by redesigning the case with a much more durable battery compartment door/switch combination. This newly designed SkinnyDipper was introduced as the **Mark II**, and has not suffered the same flooding problems as its predecessor. Mark II's LCD was improved with higher contrast and more user friendly display attenuated numbers *(thin and easy to read numbers)*.

Oceanic made changes in the algorithm that they were using in the DataMaster II and reintroduced it as the **DataMaster Sport**. In making the changes to the algorithm they adapted the Powell-Rogers model which made the DataMaster Sport much less restrictive with respect to underwater time than its predecessor. The DataMaster Sport also had increased depth capabilities. U.S. Divers made these same changes with their Data Scan2 to produce the **Data Scan 3**.

Dacor Corporation made several improvements to their Micro Brain and re-introduced this upgraded model as the **Micro Brain Pro Plus**. The Pro Plus was based on the latest research of Dr. Buhlmann and Dr. Hahn. This six tissue compartment computer utilizes half times of 6-600 minutes and the newer P-4 program.

The final modification made in 1989 of an existing dive computer came from Uwatec in the form of the **Aladin Pro** which was distributed in the United States by Beuchat. The main changes in the Aladin Pro compared to its predecessor the Aladin were that the Aladin Pro scrolls adjusted no-decompression limits between dives allowing pre-dive planning, and the addition of an audible ascent alarm.

U.S. Divers also introduced two completely new models, the **Monitor I** and **Monitor II**, that are manufactured by Uwatec. These Swiss made computers use the more conservative Buhlmann decompression model. They incorporate six tissue compartments with half times from 6 to 320 minutes. The Monitor I is a no-decompression computer and the Monitor II is a full decompression computer

At the close of 1989, Orca introduced the **Delphi**, a totally new computer design. The Delphi is a comprehensive system providing decompression status and a full range of air functions. It incorporates many of the features contained in the Edge as well as adding air consumption information by remaining air time. This was also the first dive computer to incorporate a dive profile recall interface to a personal computer (PC). Mares, the distributor of the Mentor, which is basically the Delphi with a different name, introduced their dive computer in late 1989. The Mentor is identical to the Delphi except the tissue loading bars are absent.

1990 Models

There were several new and different dive computers introduced in early 1990. Manufacturers, through technological advancements, were getting more sophisticated and provided additional features.

Oceanic introduced the **DataMax Sport**. This compact, simple-to-use dive computer was based on the Powell-Rogers research like the DataMaster Sport. This same dive computer was also distributed by Sherwood under the name of the **Source**. Tekna finished their final testing of the **Computek** and began shipping in late 1990. This Hahn-Tekna Model was the first backlit dive computer on the market. The Computek used 8 tissue compartments with tissue half-times ranging from 8 to 689 minutes and was unique with its simple icon-style graphic display. The Computek was a complete information system including air supply. The Aladin software was updated and called the Aladin Sport, by Beuchat. Parkway/Imperial began distribution of a new computer in late 1990 called the **Legend**. The Legend is made by Uwatec and has the same features as the Aladin Pro.

In Europe, Scubapro introduced two new versions of the Divetronic AG P-series dive computers, the **NC-11** and the **DC-11**. These new Divetronic dive computers used an updated P-5 program that helped eliminate some of the reverse profile problems allowed in many of the earlier models.

The future will undoubtedly produce even more dive computers. As advances in both electronics and decompression theory occur, these tools will become more powerful.

Chapter 2

Dive Computer Theory Development

Normally the body is considered saturated at sea level since the nitrogen pressure dissolved in the body and the nitrogen in the air are in equilibrium.

(**Equilibrium** – noun. [*aequus*, equal + *libra*, a balance]; **1**. A state of balance or equality between opposing forces, **2**. A state of balance or adjustment of conflicting desires, forces, etc.)

The major purpose of a dive computer, or a dive table, is to account for the theoretical nitrogen absorption and subsequent nitrogen elimination in a diver's body during and after an exposure to increased pressure. Nitrogen absorption is referred to as in-gassing *(or on-gassing)* and occurs when nitrogen pressure in the breathing gas is greater than nitrogen dissolved in the body.

Nitrogen elimination is referred to as out-gassing *(or off-gassing, de-gassing)* and occurs when ambient nitrogen pressure is less than the body's *(or tissue's)* dissolved nitrogen. The actual goal, of course, is to reduce the probability of decompression sickness in a diver as much as possible. Given this goal, it was thought possible to design a device *(our dive computers of today)* that could do this simple accounting task.

There are various models that accomplish this nitrogen accounting task. Models theoretically represent the physiology of nitrogen absorption and release in a diver's body. The main task of the model is to account for the phenomenon that as a diver descends underwater, ambient pressure increases. This increased pressure causes gases to start to dissolve in the body tissues at increased rates. The application of these concepts actually result in similar but distinctly different models on which today's dive computers are based.

In-gassing / Out-gassing

Before explaining these models it is important to realize that there are a variety of factors that determine the rate and quantity of gases that dissolve within a diver's body. These concepts are discussed thoroughly in the next chapter. This chapter contains a brief overview to facilitate discussion of these models.

Nitrogen, as far as humans are concerned, is an inert *(inactive)* gas. This inert gas makes up approximately 79% of the air we breathe. Nitrogen is not used by, nor is it normally harmful to, the human body. It is, however, the gas responsible for causing decompression sickness in sport divers. This is due to the body's inability to utilize nitrogen that it absorbs and to the great amount of nitrogen available in the air. This dissolved tissue nitrogen is in equilibrium *(at sea-level)* with the surrounding pressure *(surrounding pressure is referred to as ambient pressure)* of nitrogen because of the length of time that the body has been at sea-level *(usually longer than 48 hours)*. If you were to travel to the mountains *(high altitude and lower ambient pressure)*, the tissues would lose some of their dissolved nitrogen to maintain equilibrium at this lower pressure.

Making A Dive

Let's follow the process of nitrogen absorption and elimination during a typical recreational dive:

When nitrogen is inhaled as part of the air from a scuba cylinder, it is taken up by the blood in the lungs, and spread throughout the body along with oxygen. As the diver descends, the nitrogen and oxygen are at a higher ambient pressure. Oxygen is metabolized by the tissues, while nitrogen is forced into solution and absorbed by the tissues. This in-gassing of nitrogen takes time. Depth *(or pressure)*

and time at this higher pressure are the principal factors that determine the amount of nitrogen that is absorbed in the tissues.

While the dive continues, more nitrogen is absorbed by the tissues. As with all dives, the diver must eventually return to the surface. On ascent, the ambient pressure is now reduced. Tissue and blood partial pressures of nitrogen are greater inside than outside. The ideal ascent will allow out-gassing *(elimination of nitrogen)* at a controlled rate, without forming bubbles. If the pressure on the outside of the body drops too rapidly, the pressure differential will be too great, and bubbles can form. These bubbles can occur in the blood, joints, or between cells in the tissues. This is decompression sickness. Remember, the goal is to prevent decompression sickness.

Even if no bubbles were formed on ascent, there would still be a measure of dissolved nitrogen left to out-gas at the surface. This dissolved nitrogen is called **"residual nitrogen"**. The residual nitrogen will reach equilibrium after 24 - 48 hours *(or less, depending on dive depth and time)*. If another dive is made within this time period, the subsequent dive's accumulation of nitrogen will be added to this residual nitrogen. This is all dependent on what tissue types were filled and the amount they absorbed. These are some of the calculations your dive computer makes.

Body Types

Unfortunately, the human body tissues do not absorb nitrogen uniformly. Divers are individuals and nitrogen absorption and release will vary within their bodies. Every person has a separate physiological and metabolic make-up that can change daily and that is different from another individual's make-up . There are several other factors that influence the amount and rate of nitrogen absorption within the body's tissues. They include age, sex, level of physical fitness, body fat content, levels of hydration or dehydration *(and dehydration is a result of drinking alcohol)*, blood circulation, injuries that restrict blood circulation, medications or drugs that alter normal body physiology, body temperature, and level of exertion during a dive. As you can see, calculating the varied amounts of nitrogen in-gassing or out-gassing is extremely complicated. In fact, the only variables most dive computers use to calculate decompression status are depth and time and they do not consider all of the above mentioned variables.

Tissues

The body is also made up of numerous tissue types that absorb and release nitrogen at different rates. Tissues directly exposed to pressurized nitrogen, such as lung tissues and lung blood capillaries, in-gas very rapidly. These are known as "**fast tissues**". The fast tissues tend to eliminate nitrogen as quickly as they absorb it.

Tissues farthest away from the flow of this higher nitrogen-pressurized blood, such as fatty tissue and bone marrow are called "**slow tissues**". Slow tissues in-gas very gradually, the slowest taking more than 48 hours to fill. Slow tissues in turn eliminate nitrogen as slowly as they absorbed it.

There is a continuous range of tissues that fall in between these fast and slow tissue types. All of these tissue types are theoretical and simplified into a term referred to as "**compartments**".

Compartments

The reason that tissue types are referred to as compartments is to differentiate between tissues in a theoretical model and tissues in the body. To design a model that will account for in-gassing and out-gassing of nitrogen within a diver's tissues, the physiological factors must be included to make the model valid. We do not know the physiological to mathematical breakdown of body tissue types, therefore, theoretical compartments are used. Because the various areas or tissues of the body absorb and release nitrogen at different rates, *(fast through slow tissues)* the model must use theoretical compartments to sample this range. Theoretical compartments become part of the mathematical formula of a dive computer *(called an algorithm)* that calculates the theoretical absorption and elimination of nitrogen. The model, or algorithm, combines exposure time and depth with these different nitrogen up-take rates. This is not what is really occurring in your body. It is a mathematical formula that hopefully will keep most divers safe most of the time.

Half-times

Dive computer manufacturers use different algorithms for their respective computers. Model differences are separated by the choice of compartment types, or "**half times**", and the number of compartments used. There are other complex relationships, including M-values, making models different, which are, in most cases, proprietary information of the manufacturer. We will limit this discussion to half-times and number of compartments.

A tissue half-time is the time it takes for a tissue compartment to fill *(or empty)* with nitrogen 50% of the way from the old compartment pressure to the new ambient pressure. This is also referred to as "tissue speeds", and often is summarized as how rapidly tissues fill. The compartments from fast through slow fill at different speeds *(or half-times)*. The number of compartments used on their theoretical model vary from manufacturer to manufacturer, usually numbering between 6 and 12. *(See Table 2-1, page 31.)* What a greater number of compartments does to a model is increase the number of samples along the fast–slow tissue continuum. As implied from the Half-Time Value Table *(Table 4-1, page 53)*, some computer manufacturers sell to or build computers for other manufacturers, making algorithms and calculation results identical. Hence, many of the same computers are distributed under different names.

Types of Computers

Dive computers can be grouped into one of two types. These types or categories are the Table Based dive computers and Model Based dive computers. The Table Based dive computers apply direct calculations from dive tables. The two examples of Table Based computers are the DecoBrain I and Suunto's SME-USN. The DecoBrain I used the Swiss Dive Tables and allowed table based multi-level diving. Suunto's SME-USN uses U.S. Navy Dive Tables. For the purpose of this book, Table Based dive computers will not be compared with Model Based dive computers.

Model Based and Table Based dive computers are all of Haldanean Model origin *(with the exception of the Reduced Gradient Bubble Model that has some Haldanean influence)*. Model Based dive computers have the actual decompression model programmed into them and produce unique results for each unique dive. Table based computers must pigeon-hole each dive into one of the dives listed in the tables *(for the U.S. Navy no-decompression table there are 140 of these depth-time pigeon-holes)*. There are many assumptions that go into making a set of tables from a model and, because of this, models are much more flexible than tables. In order to categorize Model Based dive computers types, we have broken them down into five separate groups. These groups are **U.S. Navy Based Model**, **Spencer No-D Limits Model**, **Spencer Limits–Rogers Model**,

Swiss Model, and **Reduced Gradient Bubble Model** *(see Computer Model Genealogy page 29 and Computer Working Theory table page 31)*. Categorizing computers in this manner makes it easier to explain the attributes and anomalies associated with different models.

U.S. Navy Based Model

Dive computers based on the U.S. Navy Model currently consists of only one model, the Oceanic DataMaster II *(the discontinued U.S.Divers Data Scan 2 also is in this category)*. Developed by John Lewis for Oceanic, the model is Haldanean with a 120 minute off-gassing rate from all compartments. The number of compartments and the half-time ranges are identical to the U.S. Navy Model, but other internal differences make this model much more conservative than the U.S. Navy's Model. This model calculates nitrogen in-gassing, but does not allow credit for nitrogen off-gassing during shallower portions of a dive. This feature results in shortened bottom times when compared to other computers, especially on repetitive dives. The effect is a substantially more conservative computer than the other types. At this writing, Oceanic is planning to discontinue there model also.

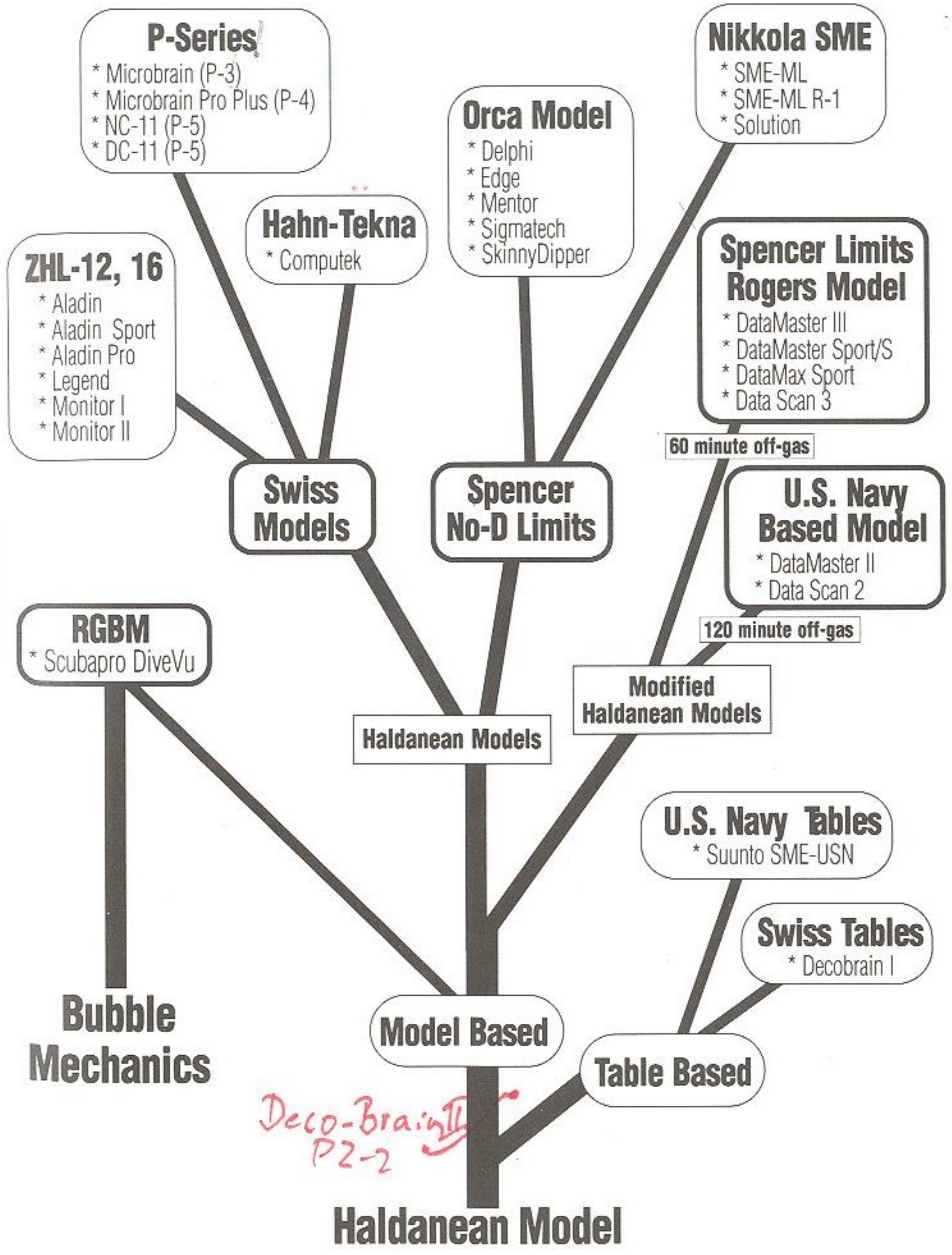
Spencer No-D Limits Model

The Spencer No-D Limits Model dive computers prove to be the most liberal computers of the groups. They are, however, a bit more conservative than U.S. Navy Repetitive Dive Tables during single square profile dives *(a square profile is a dive at the same depth for entire bottom time, except for the direct ascent)*. These computers all have models based on M. Spencer's recommended no-decompression limits, have the greatest number of compartments *(12 in most cases)* and a wide range of compartment half-times. The dive computers in this group include Orca's *(model developed by Karl Huggins and Craig Barshinger)* Edge, SkinnyDipper, Delphi, Mare's Mentor, Sherwood's Sigmatech, and Suunto's *(developed by Ari Nikkola)*, SME-MLs and Solution.

Spencer Limits–Rogers Model

The next group is derived from a modified Haldanean Model containing the Spencer Limits and the Powell-Rogers research. John Lewis used Powell-Rogers research to developed the Spencer Lim-

Computer Model Genealogy



its Rogers Model which include Oceanic's DataMaster III, DataMaster Sport and DataMax Sport, Sherwood's Source, and U.S. Divers' Data Scan 3 dive computers *(Sherwood's Source is the same as Oceanic's DataMAx Sport, and U.S. Diver's Data Scan 3 is the same as Oceanic's DataMaster III).*

Swiss Model

ZH-L12 / ZH-L16 !

The Swiss Model contains the greatest number of dive computers currently distributed. These units find a common foundation in a Haldanean Model developed by A.A. Buhlmann (ZHL-12 &16). Buhlmann developed this model originally for high altitude lake diving. Max Hahn subsequently adapted the Swiss Model for dive computers designed by Uwatec and Divetronic AG of Switzerland, and the new Tekna Computek that was co-developed by Max Hahn and Tekna of USA. Swiss Models include the ZHL-12 models dive computers manufactured by Uwatec and distributed in the U.S. by Beuchat as Aladins, Parkway as the Legend, and U.S. Divers as the Monitors. Divetronic AG manufacturers the P-3, P-4, and P-5 series dive computers which are distributed by Dacor in the U.S. as Micro Brains, and Scubapro in Europe as NC-11 and DC-11. The Tekna Computek is a Hahn-Tekna Model and is manufactured and distributed by Tekna in the United States.

The Swiss Model is more conservative in some aspects than its American dive computer counterparts *(not including the Tekna)* because of high altitude considerations, and generally more adverse conditions *(colder water temperatures).* The effect on the computers are smaller no-decompression limits on single dives and more conservative square dive profiles, allowing less bottom time. These units tend to be the best high altitude dive computers, though most of these models allow flying too soon after diving.

Reduced Gradient Bubble Model

The remaining computer falls into the Reduced Gradient Bubble Model (RGBM). This model was developed by Dr. Bruce Wienke for Scubapro USA. The model is based on Haldanean dissolved gasses and Free Phase Bubble Dynamics. This is the newest model introduced to the world of dive computers. The only dive computer at this point using this model is the DiveVu by Scubapro.

Dive Computer	Decompression Model				
	Developers	Number of Compartments	Compartment Half-Times	Computer Model	Model Type
Beuchat Aladin	A.A. Buhlmann	6	4 - 304 Minutes	Swiss Model	Buhlmann ZHL - 12
Beuchat Aladin Sport	A.A. Buhlmann	6	6 - 320 Minutes	Swiss Model	Buhlmann ZHL - 16
Beuchat Aladin Pro	A.A. Buhlmann	6	6 - 320 Minutes	Swiss Model	Buhlmann ZHL - 16
Dacor Micro Brain	A.A. Buhlmann Max Hahn	6	4 - 397 Minutes	Swiss Model	Buhlmann-Hahn P 3
Dacor Micro Brain Pro Plus	A.A. Buhlmann Max Hahn	6	6 - 600 Minutes	Swiss Model	Buhlmann-Hahn P 4
Mares Mentor	Karl Huggins Craig Barshinger	12	5 - 480 Minutes	Spencer No-D Limits	Orca
Oceanic Datamaster II	John Lewis	6	5 - 120 Minutes	U.S. Navy Model	Lewis 120 min Off-gas
Oceanic Datamaster Sport	John Lewis	6	5 - 120 Minutes	Spencer Limits Rogers Model	Powell-Rogers 60 min Off-gas
Oceanic Datamax Sport	John Lewis	12	5 - 480 Minutes	Spencer Limits Rogers Model	Powell-Rogers 60 min Off-gas
Orca Mark II	Karl Huggins Craig Barshinger	12	5 - 480 Minutes	Spencer No-D Limits	Orca
Orca Edge	Karl Huggins Craig Barshinger	12	5 - 480 Minutes	Spencer No-D Limits	Orca
Orca Delphi	Karl Huggins Craig Barshinger	12	5 - 480 Minutes	Spencer No-D Limits	Orca
Parkway Legend	A.A. Buhlmann	6	6 - 320 Minutes	Swiss Model	Buhlmann ZHL - 16
Scubapro DC-11	Max Hahn	6	6 - 600 Minutes	Swiss Model	Buhlmann-Hahn P 5
Scubapro Dive Vu	B. R. Wienke D.E. Yount	13	1 - 720 Minutes	Phase Dynamics Multi-diving	B.R. Wienke RGBM
Sherwood Sigmatech II	Karl Huggins Craig Barshinger	12	5 - 480 Minutes	Spencer No-D Limits	Orca
Sherwood Source	John Lewis	12	5 - 480 Minutes	Spencer Limits Rogers Model	Powell-Rogers 60 min Off-gas
Suunto SME-ML R 1	Ari Nikkola	9	2.5 - 480 Minutes	Spencer No-D Limits	Nikkola SME
Suunto Solution	Ari Nikkola	9	2.5 - 480 Minutes	Spencer No-D Limits	Nikkola SME
Tekna Computek	Max Hahn	8	8 - 689 Minutes	Swiss Model	Hahn Tekna
U.S.Divers DataScan 2	John Lewis	6	5 - 120 Minutes	U.S. Navy Model	Lewis 120 min Off-gas
U.S.Divers DataScan 3	John Lewis	6	5 - 480 Minutes	Spencer Limits Rogers Model	Powell-Rogers 60 min Off-gas
U.S.Divers Monitor I	A.A. Buhlmann	6	6 - 320 Minutes	Swiss Model	Buhlmann ZHL - 16
U.S.Divers Monitor II	A.A. Buhlmann	6	6 - 320 Minutes	Swiss Model	Buhlmann ZHL - 16

The performance of these different computers is discussed and evaluated in the accompanying chapters in this book. Categorizing dive computers as we have here will act as a guide throughout the remaining text. Keep in mind that it is not possible to drop each of these dive computers into a neat category that details specific performance. These categories are only meant to classify types of dive computers.

New technology is not perfect within the environment to which it is oftimes adapted. If technology was perfect there would be no accidents. We've made aircraft for over 80 years, yet they still occasionally fall from the sky. Dive computer technology is in its infancy, yet, has an amazing safety record. Divers using these new technological instruments should always remember these two things:

- **Use the information from a dive computer to make an educated decision about your dive.**
- **Dive computers do not make the dive... they provide information to the diver, who executes the dive.**

My dear Karl, once & for all:
the guy's name is
A. A. Bühlmann, his models
called: ZH-L12
(note the hyphe & the subscript!)
& : ZH-L16
The Px- are versions of varied
coefficients (a- & b-) of a
ZH-L6 or ZH-L8 !
brgds, אריק

Chapter 3

Physiology of Decompression Sickness

Most divers have also heard decompression sickness referred to as **compressed air illness**, the **bends** or **caisson disease**. It is primarily caused by the formation and growth of bubbles within either the tissues or the blood or both. The symptoms of decompression sickness are in turn dependent upon which area of the body the bubbles form. They can form whenever the body, or even part of the body, becomes supersaturated with gas. *(Refer to pages 23 - 27 in Chapter 2.)*

It is believed that gas supersaturation has occurred when the total pressure of all the gases dissolved in a tissue is greater than the ambient pressure. As a scuba diver descends, the pressure increases. As a result of increasing pressures, the diver also breathes air at higher pressures. Breathing air at these increased pressures increases the amount of dissolved nitrogen in the blood and tissues. As a diver ascends, the pressure decreases and it is possible that the total pressure of the gases dissolved in any given tissue may be greater than the ambient pressure. Should this occur, the tissue is said to be supersaturated with gas and bubbles may form. Supersaturation is a required condition for stable bubble formation. It is important to note, however, that the body is capable of tolerating some degree of supersaturation without any apparent symptoms of decompression sickness.

Understanding the process of gas intake and elimination, the concept of gas supersaturation, bubble formation, and bubble growth is fundamental to understanding the physiology of decompression sickness.

Historical Background

The initial work done in the field of decompression sickness actually had nothing to do with scuba diving. It was noticed that people working at elevated pressures in either caissons *(a caisson is a water-tight box inside which men can do construction work underwater)*, or construction tunnels, beneath rivers would succumb to symptoms of pain and paralysis. These symptoms were first witnessed in 1841 and, by the 1880's, were popularly called "the bends" because of the positions the workers took to alleviate their pain. Soon this high pressure disease was referred to as **caisson disease.** Later, in cases from hardhat divers, decompression sickness was termed "diver's palsy".

It was shown experimentally by Paul Bert, in 1878, *(La Pression Barometrique)* that the chief gas responsible for these symptoms was nitrogen. Paul Bert demonstrated that nitrogen goes into solution in the blood and body tissues during exposure to compressed air, and that it would form bubbles on too rapid decompression. These bubbles would in turn *"produce local or general blockage of the circulation or other injury."* In 1889, Dr. Moir used the first medical high pressure chamber to treat the bends during construction of the Hudson River tunnel. Subsequent experiments by Heller, Magar, and v. Schrotter in 1900, *(Luftdruckerkrankungen)* confirmed Paul Bert's original conclusions of bubble formation.

These observations led A. E. Boycott, G. C. C. Damant, and J. S. Haldane to investigate a method of prevention of compressed air illness. In the introduction of their research paper ***The Prevention of Compressed Air Illness***, *(from the Lister Institute of Preventive Medicine, 1908)* Boycott, Damant, and Haldane state:

> *It was pointed out by Paul Bert that by means of very slow decompression the symptoms of caisson disease could be avoided, but his experiments were not sufficient to furnish as to what rate of decompression would be safe. Nor has subsequent human experience in engineering undertakings solved this problem; and the risks attending work in compressed air at excess pressures of over 11/2 to 2 atmospheres are notorious.*

Boycott, Damant, and Haldane's goal was to provide information required for *"securing the safety of divers ascending from deep water."*

Their research was rendered possible by substantial financial help from the British Admiralty and the donation of a large experimental steel pressure chamber from Dr. Ludwig Mond. The steel pressure chamber was made from a section of a boiler with 5/8" steel plate walls. Inside dimensions were 7 1/2 feet long and 7 feet in diameter, giving it ample room to house experimental subjects. The pressure chamber was frequently used in decompression experiments during the 18 month period prior to the publishing of *The Prevention of Compressed Air Illness.*

Although some experimentation was conducted on human subjects during the latter portion of the study, the majority of the experiments were conducted on goats. Boycott, Damant, and Haldane explained why their choice of experimental animals lead to goats:

> *A few experiments were made with rabbits, guinea pigs, rats, and mice, but for regular use goats were selected chiefly because they were the largest animals which could be conveniently dealt with and which could be obtained in considerable numbers. The questions under consideration depend in a very fundamental way upon the rate of circulation in the animal under investigation. Among the ordinary mammals this must vary with the rate of the respiratory exchange per unit of body weight and is therefore proportional to the ratio between body surface and body weight. The susceptibility of any animal to caisson disease after sufficiently long exposure to compressed air must depend in the main upon the rate at which its respiration and circulation removes the excess of dissolved nitrogen on decompression.*

Boycott, Damant, and Haldane believed that the susceptibility of any animal varied with the size of the animal. They showed in their experiments that:

> *...the time during which the venous blood remains in a supersaturated state during each round of the circulation largely determines the formation of bubbles.*

They also demonstrated that despite the fact of the temporary existence of a great supersaturation in the blood and tissues, the time of venous blood circulation was so short in small animals that no bubbles at all are formed. They concluded:

> *Thus a mouse, weighing 20 grammes..., is much less susceptible than a goat, weighting 20,000 grammes... We have indeed failed*

to produce any symptoms at all in mice on decompression in less than a minute after one hour's exposure at 75 lbs, an experience fatal to goats."(Note that 75 lbs is a dive equivalent to 168 feet.)

These experiments by Boycott, Damant, and Haldane set forth a number of principles about decompression. Haldane and his co-workers published these principles in 1908 along with a set of decompression tables. These principles have formed (with some modification) the basis for current decompression practice including the development of the original U.S. Navy Decompression Tables.

Haldane's Principles of Decompression

Boycott, Damant, and Haldane's theory is based upon several main principles. There are some assumptions that have been made that have not been proven experimentally. Even with these shortfalls, the principles do an excellent job of setting forth a model for the physiology of decompression and decompression sickness. Haldane's principles of decompression are found in the summary of ***The Prevention of Compressed Air Illness***. Following are Boycott, Damant, and Haldane's conclusions:

1. The time in which an animal or man exposed to compressed air becomes saturated with nitrogen varies in different parts of the body from a few minutes to several hours. The progress of saturation follows in general the line of a logarithmic curve and is approximately complete in about five hours in man and in a goat about three hours.
2. The curve of desaturation after decompression is the same as that of saturation, provided no bubbles have formed.
3. Those parts of the body which saturate and desaturate slowly are of great importance in reference to the production of symptoms after decompression.
4. No symptoms are produced by rapid decompression from an excess pressure of 15 pounds, or a little more, to atmospheric pressure, i.e. from two atmospheres absolute to one. In the same way it is safe to quickly reduce the absolute pressure to one-half in any part of the pressure scale up to at least about seven atmospheres: e.g. from six atmospheres (75 pounds in excess) to three (30 pounds) of from four to two.
5. Decompression is not safe if the pressure of nitrogen inside the body becomes much more than twice that of the atmospheric pressure.
6. In decompressing men or animals from high pressure the first part should consist in rapidly halving the absolute pressure: subsequently the rate of decompression must become slower and slower, so that the nitrogen pressure in no part of the body ever becomes more than twice that of air. A safe rate of decompression can be calculated with considerable accuracy.

7. Uniform decompression has to be extremely slow to attain the same results. It fails because it increases the duration of exposure to high pressure (a great disadvantage in diving work), and makes no use of the possibility of using a considerable difference in the partial pressure of nitrogen within and without the body to hasten the desaturation of the tissues. It is needlessly slow at the beginning and usually dangerously quick near the end.
8. Decompression of men fully saturated at very high pressures must in any case be of very long duration: and to avoid these long decompressions the time of exposure to such pressures must be strictly limited. Tables are given indicating the appropriate mode and duration of decompression after various periods of exposure at pressures up to 90 pounds in excess of atmospheric pressure.
9. Numerous experiments on goats and men are detailed in proof of these principles.
10. The susceptibility of different animals to compressed-air illness increases in general with their size owing to the corresponding diminution in their rates of circulation.
11. The average respiratory exchange of goats is about two-thirds more than that of man; they produce about 0.8 gram. of CO_2 per hour per kilogramme of body weight.
12. The mass of the blood in goats is six and a half or seven and a half per cent of the "clean" body weight.
13. The individual variation among goats in their susceptibility to caisson disease is very large. There is no evidence that this depends directly on sex, size or blood-volume: there is some evidence that fatness and activity of respiratory exchange are important factors.
14. Death is nearly always due to pulmonary air embolism, and paralysis to blockage of vessels in the spinal cord by air. The cause of "bends" remains undetermined; there are reasons for supposing that in at least many cases they are due to bubbles in the synovial fluid of the joints.
15. In our experiments bubbles were found post-mortem most freely in the blood, fat and synovial fluid; they were not uncommon in the substance of the spinal cord, but otherwise were rarely found in the solid tissues.

Let's identify some of the fundamental principles which can be extrapolated from Haldane's summary:

Principle # 1

The first principle partially states "***...The progress of saturation follows in general the line of a logarithmic curve...***" This principle is actually relatively simple to grasp. A diver that has breathed air at sea level for several days should have a partial pressure of nitrogen within the body equal to the partial pressure of nitrogen in the alveoli of the lungs. Under these conditions it would be said that the diver is saturated at 1 atmosphere because there would be no net exchange of nitrogen *(or* *other inert gases)* between the diver's body and the surrounding atmosphere. This is actually a state of equilibrium and not true saturation because the tissue gas pressure remains slightly less than the ambient pressure which is a condition known as inherent unsaturation.

If a diver were to descend to depth and remain at that increased pressure for several days, all the body tissues would again become saturated with nitrogen or inert gas at the new elevated pressure. This process takes time and does not happen instantly. There are two reasons why this equilibration of gas takes time. First, each tissue has a capacity for dissolved gas that is determined by the solubility of the gas in that particular tissue. Secondly, the gas molecules must travel from the alveoli within the lungs by means of the bloodstream to the tissue where it must in turn diffuse from the capillaries to all parts of the tissue. The rate-limiting step of this process in most cases is thought to be the tissue's rate of blood flow *(perfusion)*. Gas uptake under these conditions is said to be perfusion limited. In a few tissues where the diffusion distance is great relative to the blood flow, the saturation process is said to be diffusion limited.

As the nitrogen *(or inert gas)* pressure of the tissues approaches the pressure within the alveoli, the driving force for the transfer of gas from the lungs into the tissues diminishes and as a consequence the rate of gas transfer also decreases. The net result is that the partial pressure of nitrogen within the tissues increases rapidly at first and then slows down. This type of change is exponential *(or logarithmic)* with respect to time. Exponential changes are found frequently in nature with radioactive decay being one well known example. As with radioactive decay, the rate of the process is often referred to in terms of half-times. The concept of gas uptake and elimination with respect to tissue half-times is the topic of the next chapter.

The second part of this concept is the elimination of gas during ascent. Haldane states: ***"The curve of desaturation after decompression is the same as that of saturation, provided no bubbles have formed."***

The elimination of gas from the tissues following a decrease in pressure is often assumed to occur in a manner analogous to gas uptake. It is important to understand that this assumption will not hold true if there is significant bubble formation because part of the gas then diffuses into the bubbles within the tissues instead of providing the gradient for diffusion from the blood to the alveoli.

Principle # 2

The second principle of decompression that can be summarized from Haldane is that ***"The time in which an animal or man exposed to compressed air becomes saturated with nitrogen varies in different parts of the body from a few minutes to several hours."*** To restate what was said previously, the rate at which a given tissue becomes saturated at a new pressure depends upon both the solubility of the gas in that tissue and the rate at which the gas is transported to that tissue via the bloodstream.

As most divers have heard, nitrogen is more soluble in fat tissue than in aqueous *(water)* tissue. Fat tissue has poor blood flow *(in other words it is poorly perfused)* but it has a high capacity for nitrogen. This results in fat tissue taking a long time to become saturated. For this reason, fat tissue is often referred to as a slow tissue. In contrast, the brain has a high blood flow *(or is well perfused)* and it consequently becomes saturated very rapidly. The brain is often referred to as a fast tissue.

The exponential nature of the rate of gas intake and elimination makes it nearly impossible for the saturation time to be determined. Again, these times are often referred to in terms of tissue half-times which is the time it would take for the tissue to become half saturated. Be advised that it is nearly impossible to assign exact tissue half-times to real tissues. It has become a practice to assign theoretical tissue half-times for the calculation of decompression tables. Be aware that these theoretical tissue half-times do not correspond to any specific tissues and that perhaps it would be more accurate if these were referred to as theoretical body compartment half-times. This topic is covered at some length in the next chapter. As an historical reference, Haldane's work used half-times compartments that ranged from 5 minutes to 75 minutes.

As a diver ascends, the pressure is reduced and decompression occurs. The nitrogen *(or inert gas)* that is lost through the lungs comes from many tissues simultaneously. In the early stages of the decompression much gas is lost. As the time progresses, only the slow tissues will retain significant levels of nitrogen and these slower tissues will eventually be the only tissues that will be contributing to gas elimination.

Since the rate of saturation is largely dependent upon blood flow, anything that changes the blood flow characteristics of a diver may affect the rate of gas intake or elimination. It is important to understand that susceptibility to decompression sickness varies among individuals and even the same diver from day to day. Predisposing factors which may affect either blood flow rates or gas solubility include obesity, exertion, poor physical conditioning, aging, cold, dehydration, and an injury or scar tissue causing poor circulation.

Principle # 3

The third principle that we derive from Haldane's decompression theory is that ***"In decompressing men or animals from high pressure the first part should consist in rapidly halving the absolute pressure: subsequently the rate of decompression must become slower and slower, so that the nitrogen pressure in no part of the body ever becomes more than twice that of air."*** This principle was the subject of some debate after Haldane's conclusions were reported. Haldane's belief was that the object of decompression was to surface as rapidly and safely as possible. He concluded this could be accomplished by halving absolute pressure, and then slowly continuing the decompression process without exceeding twice the surface pressure and thus not causing decompression sickness. In commercial or military diving, this is still the objective.

Before Haldane's model, decompression was often linear or uniform. Haldane's concept was a bit scary to the users of linear decompression models at the time. This linear decompression meant that ambient pressure was slowly decreased at a constant rate from beginning to end *(20 minutes an atmosphere, or 20 minutes from 33 feet!)*. So those used to using the linear models had difficulty believing that a direct ascent could be made from their working depth to a pressure equal to 1/2 their absolute working pressure. An analogy might be like trying to approach the edge a cliff as fast as possible to look over the edge without going too far and falling off.

Haldane's reasoning was that the rapid decrease in pressure would cause a supersaturation of the fast tissue which would in turn increase the rate of gas elimination as well as reduce the gradient driving gas into the slow tissues. Haldane also pointed out the importance of the initial pressure decrease being limited to the amount of supersaturation that the tissues could tolerate without bubble formation.

The ascent rate in Haldane's original tables was approximately 20 to 40 feet sea water per minute, which was approximately 20 times faster than the linear decompression technique. This ascent rate is well within the range of most of the dive computers used

ascent rate which directs a diver to slow the rate of ascent as the diver decreases depth. *(See chart on page !!!!)* All of the computers currently on the market have slower or equal ascent rates prescribed by the U.S. Navy tables. Studies indicate that these slower ascent rates are safer and help eliminate the formation of micro bubbles within the body.

Principle # 4

The final principle we will look at from Haldane is that ***"Decompression is not safe if the pressure of nitrogen inside the body becomes much more than twice that of the atmospheric pressure."*** Haldane found that men could work at pressures of two atmospheres for several hours and then be decompressed rapidly to a pressure of one atmosphere without suffering from any symptoms of decompression sickness. Haldane used these results to deduce that decompression would be safe as long as tissue supersaturation did not ever exceed more than about twice ambient pressure. This is where the Haldane 2:1 ratio came from. .

Later work by the U.S. Navy indicated that longer half-times or "slower" tissues existed than those originally proposed by Haldane. Experimental results allowed the critical ratio *(to prevent decompression sickness)* between tissue nitrogen pressure and ambient pressure to vary for the various compartments in the model. The allowable ratio was found to be greater for the more rapid or "fast" tissues. Only the slower tissues were found to agree closely with Haldane's ratio. Incidentally, this makes sense since Haldane's ratios were based on full saturation exposures and these exposures would have saturated the slowest tissue making them the critical factor.

The current concept along these lines deals with the maximum pressure of nitrogen within a group that can be safely tolerated at any depth without bubble formation. This maximum pressure value is known as the M-value. The M-value is often represented as nitrogen pressure in feet of seawater absolute *(fswa)*. M_0 equals surface M-value, and M_{10} represents the M-value at 10 feet seawater. More about this topic will be presented in the next chapter.

Beyond Haldane's Principles

There are three areas which need to be covered beyond Haldane's principles in order to make the picture of decompression more complete. These areas include the principles of inherent unsaturation, bubble formation, and bubble growth.

Inherent Unsaturation

Previously the concept of supersaturation or saturation was discussed and it was also stated that it is not actually possible for the body to become completely saturated. This inability of the body to become completely saturated is referred to as inherent unsaturation. True saturation exists when the total gas pressure within a liquid or tissue is equal to the ambient gas pressure. In the case of breathing compressed air, the total gas pressure within the body is composed of the sum of the partial pressure of nitrogen, oxygen, carbon dioxide, trace gases, and water vapor. Then the sum of the partial pressures of these gases within the body must equal the ambient pressure in order for saturation to occur.

As an overview of the respiratory and metabolic processes, the following conditions occur. The arterial blood is nearly saturated whereas the venous blood and the tissues are not. As a diver inspires dry, compressed air from a scuba cylinder it is first moisturized which essentially dilutes the air with water vapor. Within the alveoli, the oxygen is lost through diffusion into the bloodstream and carbon dioxide is gained. The total pressure within the lungs, however, remains at ambient pressure because the airway is open to the ambient pressure. The blood in the pulmonary capillaries that surround the alveoli is generally equilibrated with the gas in the alveoli. As this blood is transported it generally mixes with some deoxygenated venous blood from the heart and lungs which causes the arterial blood to have a slightly lower partial pressure of oxygen than the gas contained in the alveoli.

As this arterial blood is transported throughout the body via the capillaries in the systemic tissues it loses oxygen and picks up carbon dioxide. Carbon dioxide is more soluble in blood than oxygen and as a consequence it gives a more reduced partial pressure within the blood than oxygen does. The net result is that the deoxygenated and carbon dioxide rich blood leaving the systemic capillaries and becoming venous blood is unsaturated relative to the gas pressures within the lungs. The tissues within the body tend to be in equilibrium with the venous blood as opposed to the arterial blood. It comes back to the fact that the tissues within the body have an inherent unsaturation of gases relative to the gases within the lungs.

The importance of this inherent unsaturation during decompression is that it provides a margin of safety because it tends to oppose the formation of a supersaturated condition.

Bubble Formation

In order for decompression sickness to occur following the development of either a saturated or supersaturated condition two events must occur: First a bubble must form, and then it must grow.

Bubble formation within the body is poorly understood at best. It is believed that animals have some form of nuclei for bubble formation within their bodies. This belief stems from the fact that bubbles may form within animals well below the supersaturation pressures that are required for bubble formation in pure water. Although these nuclei for bubble formation have not been clearly identified, it is important to realize that some form of nuclei must exist in order for the bubbles to form as readily as they do.

Bubble Growth

Once a bubble is formed its growth to a larger bubble is better understood. In order for a bubble to grow in size, the gas pressure within the bubble must be greater than the external pressures acting upon the bubble or less than the surrounding dissolved gas pressures. There are four forces that act upon a bubble to restrict its growth. First, there is ambient pressure. As ambient pressure is decreased during decompression a bubble may grow according to Boyle's Law. Secondly, there is a pressure exerted by the tissue because it tends to resist the deformation caused as a bubble enlarges. Thirdly, there is an inherent resistance to growth caused by the surface tension of the bubble. Finally, there is dissolved gas surrounding the bubble.

Bubble Size and Location

The critical factor in dealing with decompression sickness is the formation of bubbles, their size, and finally their location.

Bubble formation may be prevented by maintaining a small difference between the tissue gas pressure and the ambient pressure during ascent. This is becoming a more accepted practice as is indicated by the advent of deeper but longer decompression stops being recommended by some experts. Note that this is a more conservative modification of the previously used practice of decompressing a tissue based on the Haldane ratio of 2:1.

The size of the bubbles can play a role in determining the symptoms or lack of symptoms in decompression sickness. Studies using Doppler bubble meters have been conducted. A Doppler meter is a scientific instrument that is used to detect nitrogen bubbles in the blood. The Doppler meter functions by emitting ultrasonic sound waves that are reflected from bubbles which are carried in the bloodstream. Note that the Doppler meter is not effective for detecting non-moving bubbles.

These studies using the Doppler meters have demonstrated that it is possible for a diver to have the formation of some bubbles that produce no symptoms of decompression sickness. These have been referred to as silent bubbles.

Finally, once the bubbles have formed in the body, their location will certainly influence the type of symptoms that may occur. Based on symptoms alone, decompression sickness is often put in one of two categories. Type I is often referred to as decompression sickness that produces "pain-only bends" or "skin bends". Type II includes manifestations that result in neurological damage.

Another Theory

The five original compartments that Haldane used to create his decompression schedules (5, 10, 20, 40, and 75 minutes) were implemented in decompression calculations for fifty years. Each of these compartments were limited to the ratio of dissolved nitrogen partial pressure *(tension)* to ambient pressure of 1.58:1. The U.S. Navy, after performing deep dive experiments and expanding their table depth ranges, changed Haldane's compartments to 5, 10, 20, 40, 80, 120 minutes with each tissue compartment having its own critical pressure *(M-value)*. These new changes first appeared in the ***U.S. Navy Diving Manual*** published in 1959. Table 4-2 *(page 57)* shows the U.S. Navy M_0-values for each of their compartments.

Increased diving activity of the 1960's and '70's prompted more changes to the basic format. New tissue compartments and M-values were added when existing models failed to remain safe with exposure data. As pointed out by Dr. Bruce Wienke, a nuclear physicist at Los Alamos National Laboratory, *(Multi-Tissue Algorithm and Issues; Sources 1989)*:

> *"But adding new compartments does not imply optimality nor correctness, and slower tissue compartments do not necessarily give the model proper physical signatures."*

Today, many researchers of bubble mechanics believe that the multi-tissue algorithm *(Haldanean theory)* is piecewise safe over tested ranges, but less fundamental or general. There are too many gaps in the current algorithms used in tables and dive computers. Previously, various strategies for decompressing humans have been initiated on trial and error scenarios based on past mistakes. The multi-level, multi-day, and repetitive diving typically done by recreational divers may not fit within the Haldanean model. Simply put by David Yount, Ph.D., *(Bubble Mechanics, Implications for Safe Ascent, 1990)*:

> *"Tables differ widely, both in the duration of the stops and in the ascent rates of the stops, with no apparent justification. Under these circumstances, it may be useful to try a new approach based on verifiable physical principles and especially on the mechanics of bubble formation."*

These bubble mechanic theorists have generated a more complete approach. They used both **dissolved phase** *(Haldanean)* and **free phase** bubble mechanics to develop a model which, according to the developers, safely encompasses the entire spectrum of recreational diving. Their studies on bubble growth and origination has resulted in a totally new set of dive tables and a new dive computer algorithm for Scubapro. Unlike Haldanean models which limit diving with M-values, their bubble models also limit permissible free phase buildup during diving.

Free Phase Dynamics

Bubble mechanics is based on research by Richard Strauss *(Bubble Formation in Gelatin: Implications for Prevention of Decompression Sickness, 1974)* at the University of Hawaii. Dr. Strauss began his research when he notice many commercial Hawaiian divers grossly violated accepted U.S. Navy tables schedules and got away with it. Physicist professor David Yount, Dr. Thomas Kunkle, and Dr. Ed Beckman all have continued the research. This theory, called **free phase dynamics**, is founded on the premise that **micronuclei**, or "bubble formation nuclei" *(also known as "bubble seeds")*, are present in nearly all liquid media, including animal tissue. Most micronuclei are less than one micron in diameter. *(Red blood cells are three microns in diameter and the Doppler meter cannot detect bubbles less than 20 to 30 microns in diameter, to give a size comparison.)* From stable "bubble seeds", micronuclei become unstable when subjected to pressure changes. As micronuclei grow, they become "excitable", and they grow more readily into bubbles. In a diver, when tissue pressure increases and ambient pressure decreases, gases diffuse from the tissue into the bubble. This increased internal bubble pressure causes the bubble to grow. The growth rate is dependent on differential pressure between tissue tension and ambient pressure. Continued growth of bubbles will, at some point, create symptoms of decompression sickness. Data points of bubble size can be calculated and correlated to tables or models that prevent decompression symptoms.

Another part of the theory is that during descent micronuclei are crushed into smaller sizes. The greater the surrounding pressure *(the deeper the dive)*, the smaller the micronuclei are made. These reduced micronuclei seem to stabilize at their new smaller size and are less likely to become "excitable" and grow. It was harder for them to become larger bubbles. The object is to control the size of the bubbles and keep them from expanding. In practice, this works on short deep dives, while longer deep dives saturate tissues with "excitable" growing bubbles leaving the body unable to properly eliminate them.

The primary difference between the Haldanean dissolved phase dynamics and the free phase dynamics is that gas elimination in free phase increase with depth and gas elimination in dissolved phase decrease with depth. Dissolved phase thus treat bubbles after they occur, while free phase tends to minimize the occurrence of bubbles.

Algorithms of this theory have been developed by Dr. Bruce Wienke into a working model and a dive computer with Scubapro This new dive computer is called the **DiveVu** and will be out in 1991. Until released, Dr. Wienke has these recommendations:

- **Limit respective dives to a maximum of three dives per day, not exceeding the 100' level.**
- **Avoid multi-day, multi-level, or repetitive dives to increasing depths.**
- **Wait 12 hours before flying after nominal diving, 24 hours after heavy diving (taxing, near decompression, or prolonged repetitive) activities.**
- **Avoid multiple surface ascents and short repetitive dives (spikes) within surface intervals of 1 hour.**

- **Surface intervals of more than 1 hour are recommended for repetitive diving.**
- **Safety stops for 2 - 4 minutes in the 10 - 25 feet zone are advisable for all diving, but particularly for deep (near 100'), repetitive, and multi-day exposures.**
- **Do not dive at altitudes above 10,000 feet using extrapolations of Haldanean tables.**

And he advises:

> *"Always dive conservatively, remembering that tables and meters are not bends-proof. Procedures such as these above are helpful and effective in dealing with shortcomings of the Haldanean scheme. In the broad sense, they are fixes for an incomplete theory."*

Chapter 4

Tissue Half-Times and M-Values

Compartments

In earlier chapters, it was mentioned that dive computers, as well as dive tables, were actually based on mathematical models. These models consist of mathematical formulas or algorithms that account for the effects of pressure and exposure time at depth in relationship to nitrogen absorption and elimination within a diver's body during a dive. Models segregate the body into a variety of compartments or theoretical tissue types. These body tissue types do not directly correspond to nitrogen absorption. Note that tissue types or compartments are theoretical and, accordingly, they only attempt to approximate what is occurring within a diver's body. The mathematical formulas or algorithms used for the various computers and tables are very similar. A major difference in the performance of the various dive computers or dive tables is largely dependent upon the manner in which the theoretical tissues (compartments) and their M-values are defined.

Nitrogen Tension

Some basic concepts will help in defining these theoretical compartments. **Nitrogen tension** is how much nitrogen the tissues have absorbed, and it is measured in pressure units, not volume units. The pressure units here are listed in **feet of sea water absolute** *(fswa)*. Nitrogen tension increases as ambient pressure increases *(as a diver descends)*, but since the compartments can only be filled at certain rates, it takes time for nitrogen tension to equalize with the ambient pressure. Thus, deeper dives and/or longer bottom time increases tissue nitrogen tension. Conversely, longer times between dives *(or longer **surface interval times**)* decreases nitrogen tension.

One way nitrogen tensions are measured is in feet of sea water absolute. This measurement refers to the pressure of nitrogen in the compartments. As an example, the nitrogen tension of your body tissues at sea level is 26.07 fswa. At sea level the pressure is 1 atmosphere which is equivalent to the pressure of 33 feet of sea water absolute *(fswa)*;*(79% of 33 feet sea water absolute = 26.07 fswa)*. Living at high altitude, like Lake Tahoe, Nevada or Denver, Colorado, would create a lower nitrogen tension in your tissues because of the lower ambient pressure. Nitrogen tension equilibrates at various speeds in different tissue types.

Fast Tissues and Slow Tissues

Tissue types or compartments are often described as either **fast tissues** or **slow tissues** with a continuous number of intermediate tissues. This is termed a **multi-tissue model**. Simply stated, the speed of a tissue type or compartment refers to the relative rate that it either absorbs *(in-gasses)* or eliminates *(out-gasses)* nitrogen. This model does not apply a direct mathematical computation to correspond with specific body tissues, it represents a mathematical approximation as to what occurs.

A fast tissue would absorb and eliminate nitrogen rapidly. Examples of actual fast tissues include blood, lungs, body organs, and the brain. High tissue blood flow (**perfusion**) and the capacity of the tissue to quickly absorb nitrogen *(or inert gases)* makes one tissue faster than the other. After a dive, fast tissues usually have higher nitrogen tensions than slow tissues because they absorbed more nitrogen with the same time and ambient pressure exposure.

A slow tissue in contrast would absorb and eliminate nitrogen

relatively slowly. Slow tissue examples include bone marrow, cartilage, fat, and scar tissue. Slow tissues are less vascular than well-perfused fast tissues. The lower blood flow to these tissues is responsible for less nitrogen absorption, which produces smaller nitrogen tensions.

There are also a variety of tissue types that lie between these two extremes in the rates at which they absorb and eliminate nitrogen during a dive. In order to put the various tissue types in the mathematical decompression models, they are assigned a theoretical numerical half-time value. These half-time values for the various tissue types or body compartments allow the nitrogen absorption and elimination during a dive to be mathematically approximated.

Half-Times

As explained earlier, body tissues are composed of different materials and have diversified blood supplies. It takes time to increase *(or decrease)* nitrogen tension. Nitrogen tension in tissues increases according to the rate that each tissue will allow the nitrogen absorption. So, tissues absorb *(or eliminate)* nitrogen at different rates. These different rates are called half-times.

The term tissue **half-time** refers to the theoretical amount of time *(in minutes)* that it takes for a tissue to become half-saturated *(filled)* with nitrogen. Conversely it also refers to the amount of time that it takes for the concentration of nitrogen in a tissue to decrease by one half.

In order to understand this concept of tissue half-times consider the following example of how a tissue would fill up using a tissue half-time of 5 minutes *(a fast tissue half-time)*: At five minutes the tissue would be half full *(half saturated)* or 50% saturated. It would take an additional 5 minutes to fill the remaining empty part of the compartment half full again. Filling this remaining half of the compartment would consist of half of a half or 25% of the total compartment. This would represent a total of two tissue half-times which in this example equals 10 minutes. The compartment would be 50% + 25% full for a total of 75% full. It would take an additional or third half time to fill the remaining 25% half full. After the third complete half-time the compartment would then be 50% + 25% + 12.5% which equals 87.5% full. This same process may be followed for each additional tissue half-time. After six tissue half-times the compartment would be 98.4% filled or almost completely saturated.

It is considered that the tissues are completely saturated after six tissue half-times because they are at 98.4% full, which is very close to 100%. In the above example, the fast tissue with a half-time of 5 minutes would be considered saturated after 30 minutes.

Conversely, this tissue would take a total of six half-times *(6 X 5 mins. = 30 mins.)* to return to it's normal state *(desaturate)*. From the above discussion, six times the compartment half-time becomes the factor to determine the time it would take for complete compartment in-gassing or out-gassing *(see figure 1)*.

Half times of dive computer models are shown in Table 4-1 *(page 47)*. Note that half-times range from 1 minute to 720 minutes in the models represented in Table 4-1. Different models use varied half-time ranges that result in dissimilar working dive computers. How many and which half-times used are dependent on what the developer of the model wants in performance from the dive computer. The more half-time compartments and the more extended the range of the compartments, the greater the amount of information will be provided by the model.

Sport Diving Dive Tables

Let's stop for a moment to consider the U.S. Navy dive tables. The Navy tables *(also the Jeppessen, NASDS, NAUI, Dacor, and Nu-Way Tables)* are based on a model with a 5 to 120 minute range of half-times. This model has 6 total tissue half-time compartments. Based on this theoretical model it would take at least six times the slowest tissue half-time for the nitrogen levels in the body to return to normal following a dive. Multiplying the slow tissue of 120 minutes by six would mean that it would take 720 minutes for the slowest tissue to return to normal from a completely saturated state. A time of 720 minutes is equivalent to 12 hours.

NOTE: Another way to calculate 6 half-times is to move the decimal point once over to the left *(divide by 10)* and change minutes to hours. Examples are: A 5 minute halftime takes .5 hour to saturate; 120 minute takes 12 hours.

This is why the U.S. Navy tables consider a diver to be completely free of residual nitrogen after 12 hours. Consequently, after 12 hours *(120 minute half-time)* a diver is no longer on the repetitive dive table.

Unfortunately, many experts believe that this 120 minute half-time does not truly represent the time it takes for slow tissues to completely eliminate all residual nitrogen. Saturation tables, such as those developed by R. D. Workman *(NEDU 1965)*, use half-times of

Half-Times Values for Table and Computer Compartments

Table 4-1

	Faster Tissues								Slower Tissues							
U.S. Navy Tables	5	10	20	40	80	120										
A.A. Bulhmann ZHL-12	4	7.94	12.2	18.5	26.5	37	53	79	114	146	185	238	304	397	503	635
Beuchat Aladin	4	12	26	54	108	304										
Beuchat Aladin Sport	6	14	34	64	124	320										
Beuchat Aladin Pro	6	14	34	64	124	320										
Dacor Micro Brain	4	11	31	86	238	397										
Dacor Micro Brain Pro Plus	6	15	38	95	345	600										
Mares Mentor	5	11	17	24	37	61	87	125	197	271	392	480				
Oceanic DataMaster II	5	10	20	40	80	120										
Oceanic DataMaster Sport	5	10	20	40	80	120										
Oceanic DataMax Sport	5	10	20	40	80	120	160	200	240	320	400	480				
Orca Mark II	5	11	17	24	37	61	87	125	197	271	392	480				
Orca Edge	5	11	17	24	37	61	87	125	197	271	392	480				
Orca Delphi	5	11	17	24	37	61	87	125	197	271	392	480				
Parkway Legend	6	14	34	64	124	320										
Scubapro DC-11	6	15	38	95	345	600										
Scubapro Dive Vue	1	2	5	10	20	40	80	120	180	240	360	480	720			
Sherwood Sigmatech II	5	11	17	24	37	61	87	125	197	271	392	480				
Sherwood Source	5	10	20	40	80	120	160	200	240	320	400	480				
Suunto SME-ML R 1	2.5	5	10	20	40	80	120	240	480							
Suunto Solution	2.5	5	10	20	40	80	120	240	480							
Tekna Computek	8	14	25	43	75	131	227	689								
U.S.Divers Data Scan 2	5	10	20	40	80	120										
U.S.Divers Data Scan 3	5	10	20	40	80	120										
U.S.Divers Monitor I	6	14	34	64	124	320										
U.S.Divers Monitor II	6	14	34	64	124	320										

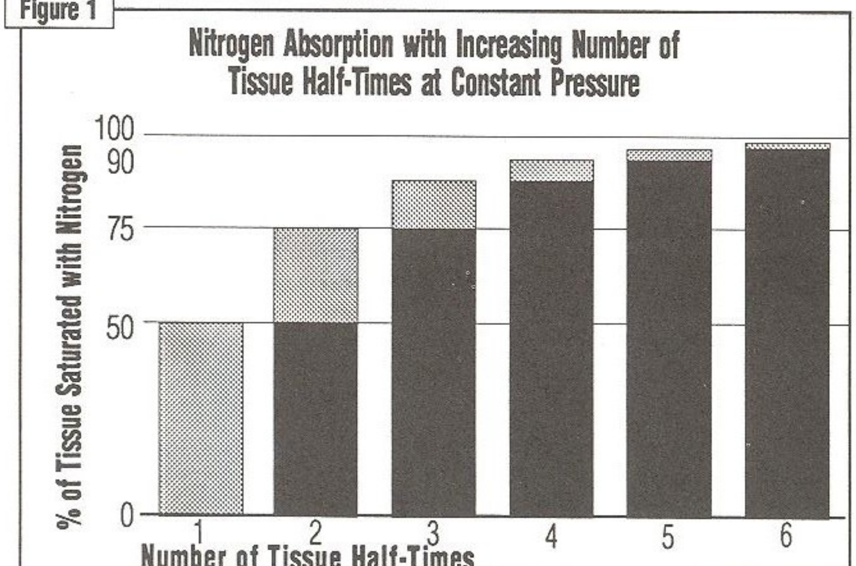
Boxes represent compartments with half-time values expressed in minutes

240 minutes, which would produce a 24 hour desaturation time. Some researchers question weather the 120 minute tissue half-time *(U.S. Navy)* is applicable to multiple day, multiple diving. Some slow tissues may take 48 hours or more to completely out-gas. In terms of tissue half-times, this would require a half-time of 480 minutes *(which is obtained by dividing 48 hours by 6 which equals 8 hours, and 8 hours is 480 minutes).*

Other Sport Diving Dive Tables

Dr. Michael Powell of the Institute of Applied Physiology and Medicine, in 1987, tested a new set of repetitive dive tables. These new tables *(the Recreational Dive Planner)* were developed by Ray Rogers, D.D.S. and have been distributed by PADI to the sport diving market since early 1988. Rogers used 8 tissue compartments with values of 5, 10, 20, 30, 40, 60, 80 and 120 half-time minutes to compute the Recreational Dive Planner no-decompression limits. However, instead of using the the 120 minute compartment for surface off-gassing like the U.S. Navy, Rogers concluded that for "recreational dives" surface off-gassing could be controlled by a 60 minute compartment. By using the 60 minute compartment as a controlling compartment, it reduces the required surface interval between repetitive dives. These tables also consider your entire body desaturated after 6 hours of surface interval time. The table accounts

Figure 1



for additional exposures by having special rules for multiple dives.

PADI conducted tests of these tables under the direction of Dr. Powell for Diving Science and Technology (DSAT). No cases of decompression sickness were found to occur after 750 exposures on human volunteers with the profiles used for the tests. These tests were 3 dives a day for a single day. The volunteer subjects were all monitored by Doppler *(ultrasound flowmeter that listens for small bubbles)* and only low grade bubbles were detected in a small percentage of the test subjects. DSAT is currently conducting a test series of 4 dives a day for 6 days.

The technology of the modern day dive computers accounts for multi-day, multi-dives by using slower tissue half-times *(480 minutes for most of the dive computers).* These slower half-times are theoretically more representative of the human body's slower tissues. The slower tissue half-times are unlikely to effect the calculations under ordinary diving conditions. They may, however, become the limiting compartment under heavy multiple dives on multiple consecutive days. Hence the slower 480 minute tissue half-time may be safer for multiple dives on multiple consecutive days with respect to decompression sickness.

Slow tissue compartments are also very important for bubble models, such as the **Reduced Gas Bubble Model** (RGBM) developed by Dr. Bruce Wienke. In fact, slow tissue compartments in bubble models are more sensitive to multi-day and repetitive multi-day diving than in Haldanean models.

A Range of Tissue Half-Times

Practically speaking, compartments that are assigned small half-time values *(fast tissues)* absorb nitrogen quickly during a dive but also eliminates it quickly following a dive. Compartments that are assigned longer half-times do indeed absorb nitrogen more slowly but they are also slower to release the gas. As a consequence, these slower tissues may contain residual nitrogen for up to 48 hours instead of the previously believed 12 hours. Keep in mind these tissue half-times are only mathematical approximations of what occurs within a diver's body. In reality, there are no exact tissue speeds or half-times that can be assigned to every diver under every environmental and physiological condition. There is actually a continuous range of tissue half-times that lie within these theoretical fast and slow tissues.

Items to consider when analyzing tissue half-times are the range *(the minimum and maximum half-time values)* and the number of intermediate compartments *(i.e. the total number of tissue half-times)* that are in the calculations. A minimal range of 5 to 120 minutes may be sufficient to determine a diver's decompression status in most sport diving. For extensive repetitive diving on consecutive days the slower compartment of 480 minutes may be paramount to safety. The more compartments that are considered, the more continuous the range is and, hopefully, the more the model represents what is actually occurring within a diver's body.

Table 2-1, entitled Computer Working Theory provides the various compartment half-times and the number of compartments used by the computers *(page 31)*. Table 4-1, entitled Half-Time Values for Table and Computer Compartments, shows how the various computer half-times compare to the U.S. Navy and the Buhlmann Models *(page 53)*.

M-Values

Another consideration must be taken into account during decompression computations. Each of the theoretical tissues or compartments will have a maximum nitrogen tissue tension that can be safely tolerated at the surface without bubble formation. This maximum nitrogen tension is often referred to as the M_0-value. M is short for maximum, and the M-value is the maximum allowable tissue tension at a specific depth. The M-value is stated in pressure units that are usually listed in feet of seawater absolute *(fswa)* as is nitrogen tension. M_0 is the maximum nitrogen tension allowed at the surface, whereas M_{10} is the maximum nitrogen tension allowed at 10 feet of seawater.

As stated previously, the partial pressure of nitrogen in the air and in the tissues of a person that has equilibrated at sea level is 26.07 fswa. Each tissue *(or compartment)* half-time has a specific M_0-value calculated for it so that critical **supersaturation** *(levels)* won't be exceeded. No compartment may exceed its defined M_0-value when returning to the surface. A higher nitrogen tension than allowed for in a compartment *(or tissue)* will, according to the model, trigger bubble growth. The object of a no-decompression dive is to surface before compartment nitrogen pressures reach their M_0-values. Safety stops, at the end of these no-decompression dives, help to drop nitrogen pressures in the compartments to lower levels before surfacing.

Compartment Half-Times and M_0-Values

Table 4-2

U.S. Navy	Compartment Half-Time	5	10	20		40		80	120
	M_0-Values (fswa)	104	88	72		56		54	52
Rogers Model (PADI)	Compartment Half-Time	5	10	20	30	40	60	80	120
	M_0-Values (fswa)	99.08	82.63	66.89	59.74	55.73	51.44	49.21	46.93

missing are M_0 for: 160, 200, 240, 360 & 480 !

As the M_0-values are approached, remaining no-decompression time becomes less and less, until it is non-existent. When the M_0-value of any compartment is exceeded, the diver has entered into a decompression dive. The nitrogen pressure in the compartment(s) must be brought down to, or below, the corresponding M_0-value(s) before the diver can surface. If the excess is in a fast compartment then the act of a slow ascent may be enough to reduce the pressure to a "safe" level. However, in most decompression dives the act of a slow ascent will not produce the required out-gassing and decompression stops will be required. According to the model, there is a depth to which the diver can ascend without nitrogen pressures violating the compartment M-values for that depth *(remember compartments have an M-value for each depth)*. This depth is generally referred to as the "**Ceiling.**"

A standard approach to the use of the Ceiling is a stepped decompression. If the Ceiling depth is 15 fsw, the diver ascends to 20 fsw and waits until the Ceiling is 10 fsw or less. The diver will then ascent to 10 fsw and decompress there until the Ceiling disappears. At this point the model indicates it is "safe" to surface. As with the safety stop in no-decompression diving it is prudent to stay at the final decompression stop depth for a few additional minutes to reduce compartment pressures further. In the same vein, it is wise to stay a few feet below the Ceiling during decompression.

Increased Risk

It is thought that there is an increased risk of decompression sickness anytime that a diver exceeds the M_0-value. The M_0-values that were used in the U.S. Navy model range from 52 fswa in the slowest tissue group to 104 fswa in the fastest tissue group. The remaining four M_0-values that were used fall in between these two values. The tissue half-times and M-values used to create the U.S. Navy tables are found in the Table 4-2.

Limiting Factors

Almost all of the modern dive computers use M-values that are lower (more conservative) than those in the Navy model. Since the M-values are an integral part of the decompression calculations that the computers performs, the net result is that the computers give more conservative no-decompression limits for single square profile type dives than the U.S. Navy tables.

The bottom line is that the dive computers run through a series of calculations using a range of compartment half-times with each compartment having its own specific M_0-value as the limiting factor for no-decompression diving. During deep dives of shorter duration the no-decompression time will be controlled by the fast tissue compartments whereas on longer, shallower dives the slower compartments limit the dive. Ultimately, less time at depth means less nitrogen absorption.

M-Values vs. Micronuclei

M-values should not be regarded as the panacea of preventing bubbles *(or decompression sickness)* in dive computer or dive table models. All any of the models attempt to do is keep most divers safe most of the time. Bubbles can form *(and have been shown to do so using Doppler studies)* when staying within prescribed M-values in many models. Some dive computers have made their models more conservative by lowering their M_0-values, but this is only a mathematical fix that does not account for every diving scenario. The phase dynamic computers (Dive Vu) focus on permissible bubble volumes, not just M-values.

Other factors and variables implicate not using M-values as the only restricting threshold. Micronuclei, discussed in Chapter 3, may "seed" bubbles long before M_0-value are reached. In view of diversified decompression research, involving many types of models and approaches to the problem of decompression, M-values should not be considered the absolute calculating limiter. The preferred practice is to minimize bubble growth of any kind. Therefore, other factors besides M-values must be involved in the final calculations of limits in future dive computers.

Chapter 5

Guidelines for Using Dive Computers

It is important to a diver's safety to always remember that dive computers are not monitoring actual nitrogen absorption and elimination within your body, but are calculating the theoretical nitrogen in-gassing and out-gassing based upon a mathematical model. The model may or may not resemble what is happening physiologically in terms of nitrogen in-gassing and out-gassing to most divers as they spend time underwater. There are a variety of considerations that must be taken into account when using a dive computer. One major consideration is to remain well within the limits or parameters prescribed by the model. This means following the guidelines for use of the particular model being used. An example of following the guidelines would be ascending at the rate specified in the model.

There are also a number of physiological factors that may put a diver either on the outer edge or completely outside the limits of the model. These factors might include poor physical conditioning, excessive obesity, dehydration, alcoholic intoxication *(or even being hungover)*, smoking, and gender. Keeping all of these things in mind, some guidelines to help a diver get the most out of a dive computer and yet remain safe within your computer limitations are presented in this chapter.

1. Read The Instruction Manual BEFORE DIVING with Your Dive Computer

Each dive computer has many different features and displays. It is very important that you read your dive computer manual carefully before diving your dive computer. A case in point is the example of one computer that has a flashing "*ascend*" light which may be misinterpreted to mean "*go up*", when it actually means that "*you are ascending too fast*".

2. All Dive Computers Should be Used for No-Decompression Diving Only

Some of the computers on the market have the capability to perform decompression diving, however, this type of diving is really beyond the realm of sport diving. Any time decompression diving is performed, a diver loses the ability to ascend directly to the surface without having to stop and decompress. In the event of an emergency, such as an out of air situation, this would place the diver in a very dangerous position. By staying within the No-Decompression Limits of the computer, emergency situations are less complicated since direct ascent to the surface remains a viable option.

3. Each Diver Should Have a Dive Computer – Do Not Share A Computer

When using multi-level techniques diving, it is essential for safety that each diver have their own dive computer. The reason for this is that even the best of buddy teams will have some variations in the amount of time spent at each particular depth during a dive. Since the computer is constantly calculating depth and time profiles, there could be some variations in the adjusted no-decompression limits for two divers that are diving as buddies. It is conceivable that these variations in depth and time at each depth could result in putting one diver in decompression situation, while the other diver had remained in the no-decompression zone. The diver who unknowingly has to make a required a decompression stop and fails to do so during ascent, increases the probability of developing decompression sickness. Each diver having and monitoring their own dive computer reduces this possibility.

4. Stay Within the Dive Computer Specified Ascent Rate

All ascents should not exceed the rate specified for the particular dive computer being used. These ascent rates are actually a form of decompression and are very important. Most of the dive computers currently available have some form of ascent rate monitor. Many times these ascent rates are slower than the original 60 feet per minute used by the U.S. Navy. They may also vary with depth during your ascent. Divers should observe their dive computer during ascent and not exceed the computer specified ascent rate.

It is believed that divers using slower ascent rates or stops may prevent the formation of micronuclei which have been observed to form when using the faster ascent rate specified by the U.S. Navy tables.

5. Dive Conservatively When Approaching The Limits While Using A Dive Computer

As was previously mentioned, there are a number of factors that may increase susceptibility to the bends. Increased age, poor conditioning, old injuries, and obesity are just a few. Because these things tend to push a diver outside the model, it is not a good idea to press the limits if any of these factors apply to your physiological make up. Diving conservatively means subtracting time from the no-decompression limits specified by the computer. Treat the dive computer as you would the U.S. Navy tables by adding in a safety margin. Dive computer limits should never be approached.

6. Do Not Turn the Dive Computer Off Before Desaturation (Outgassing) is Complete

Multi-level dive computers run until each compartment in the model is "clear" of excess or residual nitrogen. Following a series of dives it may take 24 or more hours for the model to completely out-gas. Consequently, there may be a gradual and slight reduction of the no-decompression limits over the course of a week of heavy diving even though there may have been a 12 hour surface interval between dives on consecutive days of diving. Check the computer manual for information on total nitrogen elimination.

7. Drinking Alcohol and Dive Computer Diving DO NOT Mix

Drinking alcohol changes your physiology. There are two significant ways that the physiology changes, and these may increase a diver's susceptibility to decompression sickness. Alcohol is a vaso-dilator, which changes blood flow characteristics; this in turn affects the rates of nitrogen in-gassing and out-gassing. In addition, alcohol tends to dehydrate the body. Dehydration is a major factor increasing susceptibility to the bends. Drinking alcohol and diving have never been a good combination and this includes diving with a hangover. This is especially true when multi-level diving using a dive computer. For divers who push the limits using a dive computer, be aware that a heavy night of drinking may be the variable that pushes a diver beyond the limits of the model. If you party hard, you're much safer spending the next day basking in the sun.

8. Plan Your Deepest Dive First

In a series of repetitive dives, the deepest dive should always be made first. This maximizes repetitive dive bottom time and decreases the risk of decompression sickness. Repetitive dives should be made in progressively shallower water. Multi-level dives should be initiated with the deepest segment of the dive first and the subsequent portions of the dive in progressively shallower depths. Finishing the dive in shallow water serves as a form of decompression. Avoid repetitive dives to depths in excess of 100 feet.

9. Dive Computer Failure Procedure

There are two potential types of dive computer failure. The computer might possibly fail during a dive or it could fail during a surface interval. If the computer fails during a no-decompression dive, a diver should ascend slowly but directly to the surface being sure not to exceed the manufacturer's maximum recommended rate of ascent. A short safety stop *(of 3–5 minutes)* at 10 - 25 feet adds a margin of safety. If the computer fails during a surface interval there are two alternatives. A single repetitive dive may be made using the adjusted no-decompression limit from the computer if it was recorded following the previous dive and prior to the failure. Alternatively, repetitive dives may be made to depths less than 20 feet.

10. Make Precautionary Stops Following Every Dive

It has been demonstrated that safety stops are helpful in the prevention of decompression sickness or bubble formation. Diving conservatively includes a safety stop on every dive between 10 and 25 feet for 3 to 5 minutes.

11. If the Dive Computer Fails, It is Not Possible to Return to the U.S.Navy Tables

Since most of the computers are based on different models than the U.S. Navy tables, changing from a computer to the U.S. Navy tables will not work. Dives using the U.S. Navy tables must be delayed until complete outgassing has occurred. This may take as long as 48 hours for some dive computers.

12. Flying After Diving

Many dive computers feature Flying After Diving indicators which tell a diver when it is theoretically safe to fly. Most of these indicators will allow a diver to fly within a short period of time following a day's diving. It is currently recommended that recreational divers wait at least 24 hours after diving before flying. Waiting this additional period of time can only add a margin of safety *(See Flying After Diving, Chapter 9, for recommendations).*

13. Situations To Avoid

There are three types of diving conditions that are presently allowed by current dive computer models that should be avoided:

Reverse Profile Dives

Dives where the diver spends the majority of a dive in shallow depths and then descends to the maximum depth shortly before surfacing.

Consecutive Deep Dives (dives over 60 feet)

Dives where the diver repeatedly returns to approximately the same maximum depth *(over 60 feet)* with only short surface intervals between dives.

Repetitive Decompression Dives

Dives when the diver makes a series of multiple dives that all exceed the no-decompression limits.

Caution is in Order

According to the conventional wisdom at this time, dive practices that include the three scenarios described above increases the risk of decompression sickness even though the dive computer model may indicate that they are feasible. We recommend that such practices be avoided.

15) Assure Dive Computer is On Before Diving

Make sure the dive computer is powered up and running before diving it in the water. Many of the dive computer models need to sense the atmospheric pressure before they can accurately sense depth underwater. An inaccurate start-up procedure may also put many models into an error mode.

16) A Final Note

Dive computers have given divers the freedom of multi-level diving. This freedom has allowed us to spend more time exploring and enjoying the underwater world. It is important to remember that neither the dive tables nor a dive computer can absolutely insure that a diver will not get decompression sickness. These devices are based on mathematical models that have been supported by experimentation and research. Use them properly following the manufacturer's directions and the previously mentioned guidelines. Continue to stay abreast of recent developments in decompression theory and dive computer assisted diving. Using dive computers conservatively and properly will reduce the likelihood of injury from decompression sickness.

It is important to be aware that all dives carry some risk of decompression sickness and neither the authors nor Watersport Publishing, Inc. will assume any responsibility or liability for accidents or injuries that might occur for any reason.

Chapter 6

How Dive Computers Work

One of the big questions that many people ask is "How do dive computers work?" Dive computer functions are very simple. In this chapter, a simplified dive computer diagram *(page 67)* will be used to illustrate the basic parts of a dive computer and its function. Although this is obviously a generalized description, it typifies operation of all dive computers.

The Components

A dive computer can be broken down into eight main components. These components include a power source, pressure transducer, analog to digital converter, microprocessor that has both ROM and RAM, internal clock, and display screen. Using our dive computer schematic on page 67, we can describe the function of the components of the computer as follows.

The first component to be considered is the power supply, which provides power for all of the other components in the computer. There is a great deal of diversity in the types of power supplies or batteries used in the various computers. Power requirements of the components within the different dive computers vary considerably. Consequently, there is diversity in battery consumption between dive computers currently available. For example, under constant use one computer has a battery life of one week, while there are other dive computers that have battery lives of three weeks. On the other end of the spectrum, there are several dive computers that have an expected battery life of more than five years. For the expected battery lives of the various computers compared in this text refer to the table 8-1 in Chapter 8 *(page 85)*.

Once the computer is powered up, the pressure transducer begins measuring atmospheric pressure *(ambient pressure)*. Pressure transducers read this ambient or surrounding pressure and converts it into a voltage. This voltage is then processed by the analog to digital converter.

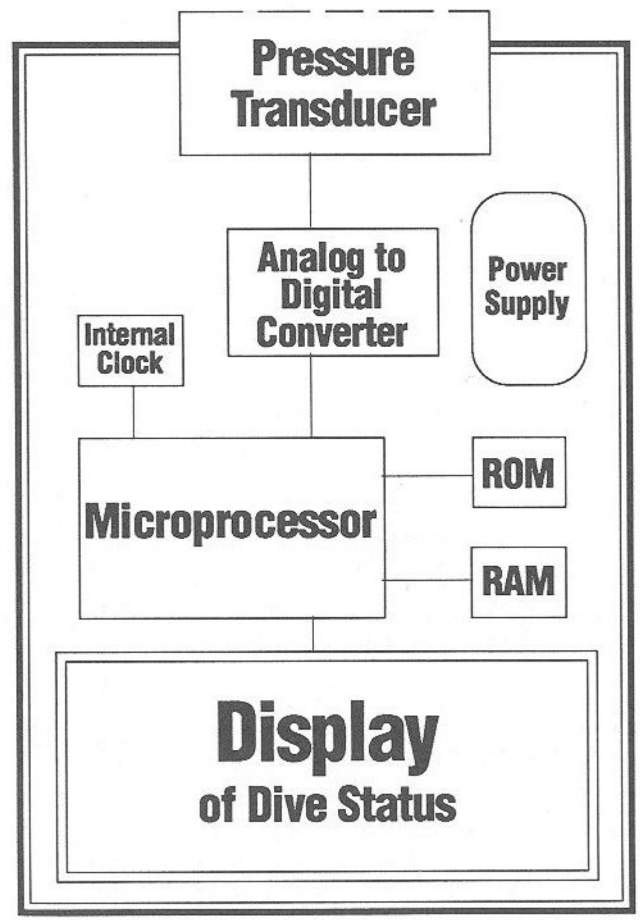
The analog to digital converter or A/D converter is the second link in the flow chart. The A/D converter takes the analog pressure transducer voltage signal and changes it to a digital signal representative of the surrounding pressure or depth, which can be used or "read" by the microprocessor. The microprocessor takes the information from this digital signal and performs all of the mathematical computations and logic operations required by the model or program.

The microprocessor uses two types of memory. The "Read Only Memory" or ROM is a permanent memory that contains all the program steps. It is the ROM that "tells" the microprocessor what steps to perform. The ROM also contains all the constants such as compartment half-times and M values that are used to calculate no-decompression status. The second type of memory is the "Random Access Memory" or RAM. The RAM contains the storage registers where the dive data and calculation results are stored.

There is an internal clock which may play a variety of functions from determining the dive computers calculation rate to the recording and display of surface interval time.

The final component to consider is the computer display screen. Again there are a variety of display formats and configurations available. The display configurations for each of the computers compared in this book are in Chapter 8. The display screen presents the diver with his current decompression status according to the specific model in the ROM. There may, however, be a multitude of data and other dive-related information *(such as air pressure, temperature, altitude compensations)* presented as well.

Computer Component Schematic



Chapter 7

Computer Assisted Multi-Level Diving

This section defines multi-level diving, discusses theoretical considerations and techniques for multi-level diving, and applies these techniques to computer assisted diving. An actual dive profile is used as an example of these techniques. In addition, dive computers with multi-level dive profile recalls are examined and samples of their profiles are shown.

U.S. NavyTables vs. Multi-Level Diving

The U.S. Navy tables *(or U. S. Navy based tables)* require a diver to compute bottom time as if the diver were at the maximum depth for the entire duration of the dive *(not including ascent time)*. These tables were originally designed for U.S. Navy divers. Most U.S. Navy divers spend their entire dive at one depth, conducting work on a specific project and then return directly to the surface.

Recreational divers have used U.S. Navy tables as a guide for calculating dive schedules since the inception of the sport. The tables are applied in the same manner as the Navy uses them. The deepest depth for the entire underwater time *(not including ascent time)* is computed. But not all recreational dives are created equal. In contrast to Navy divers, few recreational divers actually dive to and then spend their entire dive at one depth. Whether exploring a wall, coral reef, kelp bed, or wreck, most divers ascend and descend to various depths throughout the course of a single dive.

Let's look at two separate dives to the same depth with the same "bottom time". Dive #1 is a dive to 110 feet for 2 minutes followed by an ascent to 40 feet for an additional 18 minutes. Dive #2 is a dive to 110 feet for the entire 20 minutes. Each dive has the same amount of bottom time, however dive #1 will not dissolve nearly as much nitrogen in a diver's body as dive #2. The 110 feet/2 minutes, 40 feet/18 minutes dive *(dive #1)* is called a **multi-level dive**. The 110 foot/ 20 minute dive *(dive #2)* is called a **square profile dive**. Every diver learns in their beginning scuba course that the amount of nitrogen absorbed into a diver's body during a dive is dependent upon the depth *(pressure)* and length of time exposed to the pressure. From this example, it should become apparent when using the U.S. Navy dive tables, not all dives to the same maximum depth for the same bottom time will result in equal nitrogen absorption.

Multi-Level Diving

Multi-level diving takes into account the differences in the various depth segments of a dive and then computes a revised status based on the amount of nitrogen that was theoretically absorbed at each depth level.

A method of using the U.S. Navy dive tables for multi-level diving was presented by Dennis Graver in 1979. This procedure was developed by oil rig divers who used this method to "credit" for shallower portions of a dive and eliminated using the maximum depth for the entire bottom time. The method did not attain much popularity among sport divers because it required pre-planning and then constant monitoring of the various time-depth segments of a dive. Most divers were not disciplined enough to do these calculations in advance of their dive or underwater during their dive.

Dive computers, on the other hand, are able to keep track of the various time-depth segments and then apply this data to calculating the diver's decompression status. Dive computers do these calculations every 1 to 3 seconds for us. As a consequence, the computer serves as a dynamic or "living" dive table that constantly keeps a diver informed of the theoretical nitrogen levels accumulating within his/her body. The results of multi-level calculations in dive computers vary with the different models *(or algorithms)* used.

Dive computers have made multi-level diving both possible and practical. These dive computers have the capability of calculating theoretical nitrogen absorption and elimination based on the actual depth and time spent at each particular depth during the various segments of a dive. This frees the diver of the severe limitations imposed by rigid U.S. Navy table rules of having to make calculations based on the deepest depth and total bottom time, while little time may have actually been spent there.

As an example, consider a dive to 120 feet using the U.S. Navy dive tables. A quick look at the tables would indicate that the no-decompression limit *(NDL)* for a dive to a depth of 120 feet is 20 minutes. Most diving experts believe that this 20 minute NDL at 120 feet is not safe enough and recommend a more conservative NDL of 15 minutes. Based on this information, it is prudent to say that a dive to 120 feet is going to have a short no-decompression limit according to the U.S. Navy tables, and a shorter NDL according to the experts.

Test Dive

During our evaluations of the dive computers, a test dive was made to a maximum depth of 120 feet for a bottom time of 51 minutes and no decompression stop was needed during the ascent. This exceeded the U.S. Navy no-decompression limits by 31 minutes. As incredible as it may seem, none of the dive team members suffered from decompression sickness. This extended dive profile was made possible by using diving computers coupled with multi-level diving techniques. It is important to understand, however, that **at no time during this dive did we enter into a decompression schedule.** It is possible to do dives that apparently exceed the no-decompression limits set by the U.S. Navy dive tables using these techniques. Dives like this can and should be made without ever exceeding the no-decompression limits *(as specified by the dive computer)* at any time during the dive. These dives can only be made safely by understanding and properly implementing multi-level techniques and adhering to all the rules and guidelines set forth by the particular dive computer used.

Safer Techniques

Multi-level diving using dive computers can lead to greatly increased bottom times. This is especially true in contrast to the bottom times allowed by traditional U.S. Navy table-based diving methods. With this increased diving freedom comes the necessity to consider some critically important safety factors. Guidelines for safe computer usage are given in Chapter 5 and are worth reviewing.

Here are some techniques to make multi-level diving safer. Remember that each dive computer is designed to give a constant up-date on the no-decompression limit time remaining at that depth. Monitor these no-decompression limits carefully and do not ever exceed the limit and get into a required decompression mode. A required decompression stop takes away a diver's ability to ascend directly to the surface in the event of an emergency. It is wise to dive conservatively when approaching the no-decompression limits and it is smart to add in a safety factor of your own. It is not prudent to push the limits whether using a dive computer or a set of dive tables. In order to maximize time spent underwater, the beginning part of a dive should always be spent at the deepest portion of the dive followed by a stair-stepping ascent to subsequent shallower depths.

Slower Ascent Rates

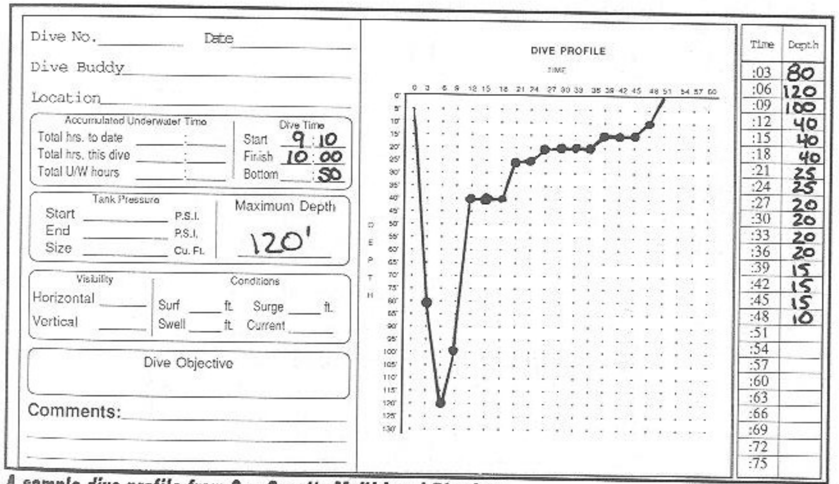
All of the dive computers on the market have specified ascent rates which are slower or equal to the 60 feet per minute rate that is specified by the U.S. Navy tables. Several of the computers even have an ascent rate of 20 feet per minute for the last 60 feet. This is a considerably slower ascent rate than the U.S. Navy tables. These slower ascent rates help in preventing bubble formation during ascent. Do not exceed the computer specified ascent rate! Exceeding the ascent rate could cause bubble formation within a diver which would result in a case of decompression sickness. Ascend slowly while continually monitoring the dive computer during the ascent.

Multi-level Dive Profile Recalls

Three of the computers on the market today *(actually four counting the ACE by Quatek in England)* have recall capabilities of multi-level dive profiles. Several other computers have recall features *(or Logs)* of previous dives, however, they do not break-down

the dive into its multi-level segments. Suunto's **SME-ML R-1** *(distributed by Sea Quest, Inc. in the United States)*, Suunto's new **Solution**, and Orca's **Delphi** have the ability to store and provide multi-level dive profiles on a time segment basis.

Suunto's **SME-ML R-1** *(their older SME-ML)* and **Solution** have the feature of recalling dive profile data by a touch of the fingers. The dive profile mode is activated by using the on/off memory contacts on the outside of the case. Scrolling of the previous dive profile data is shown in decreasing 3 minute increments with corresponding maximum depth during that 3 minute recording period *(This 3 minute scrolling is displayed in increasing increments in the original SME-ML)*. The display shows the maximum depth and dive duration before the profile is scrolled. The **SME-ML R-1** then continues scrolling previous dive profiles for up to 10 hours of stored data. The **Solution** stops its incremental scrolling after the each dive unless its memory signal is reactivated, allowing it to recall up to 8 hours of stored data, a dive at a time.



A sample dive profile from Sea Quest's Multi-Level Dive Log.

Sea Quest, Inc. produces two different memory recall logs to facilitate documentation of multi-level dive profiles. In 1989, Sea Quest published the first multi-level log book permitting their dive computer user to replicate an accurate profile of up to 75 dives. The Sea Quest **Multi-Level Dive Log** provides a dive profile grid, a 3 minute time-depth record, and typical logbook entry information. In early 1990, they introduced the first IBM software program called the **Desktop Log and Simulator**. This IBM compatible software has the capability of compiling past multi-level dives and creating multi-level profile graphs. Another part of this IBM program offers simulated dive profiles *(which can furnish demonstration dives)*. Information must be entered manually into this software system.

The **Solution** retains Sea Quest's two recall log systems and adds a third simpler electronic feature. The **Solution** can be connected directly into IBM compatible computers by a special interface using the water contacts. This interface sets up a communication between the **Solution** and the **Desktop Log and Simulator** software program that accommodates transfer of dive profile memory, without manual data entry. It also has the ability to simulate dive profiles. This interface connector system became available to **Solution** users in early 1991.

Orca's **Delphi** and **Delphi Pro** have a similar PC interface system called the **DataReader**. Dive profile information is accumulated in the **Delphi DataLogger** and stored in a permanent non-volatile memory *(memory that is not effected by power loss)*. The DataLogger files detailed multi-level dive profiles of **Delphi's** most recent 35 hours underwater. The multi-level profile data points represent the maximum depth reached during each 2.5 minute segment of time spent underwater. Surface interval time is also

Figure 1

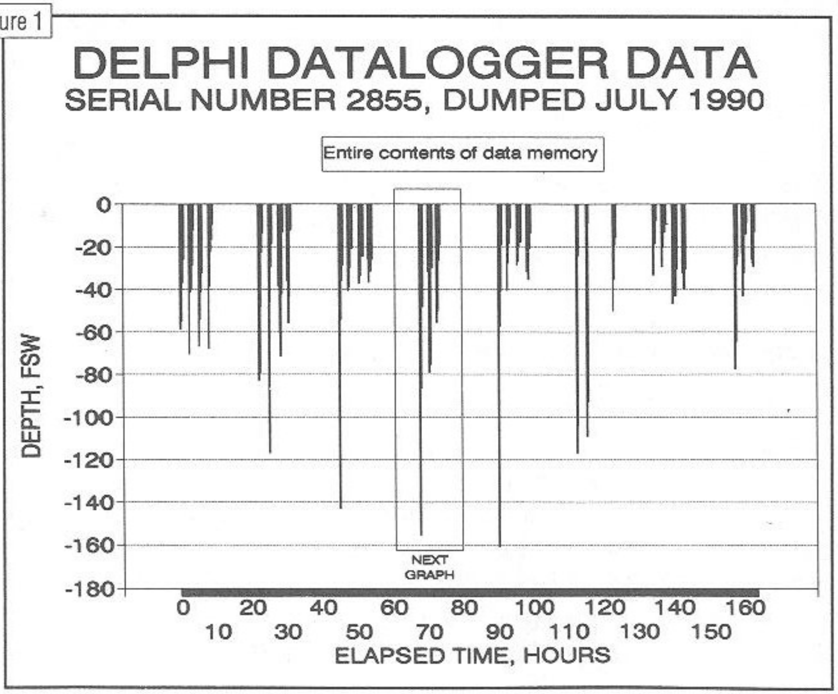
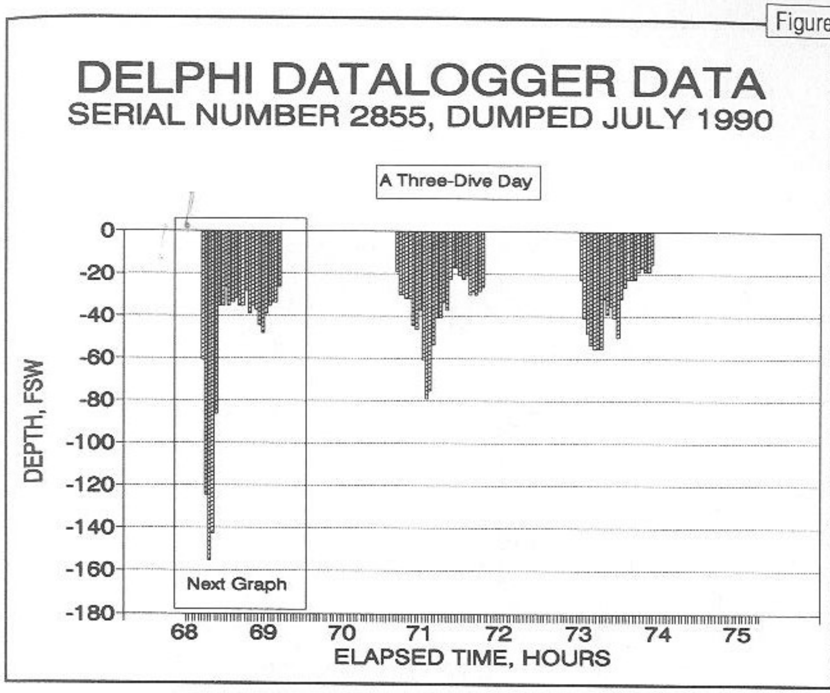


Figure 2

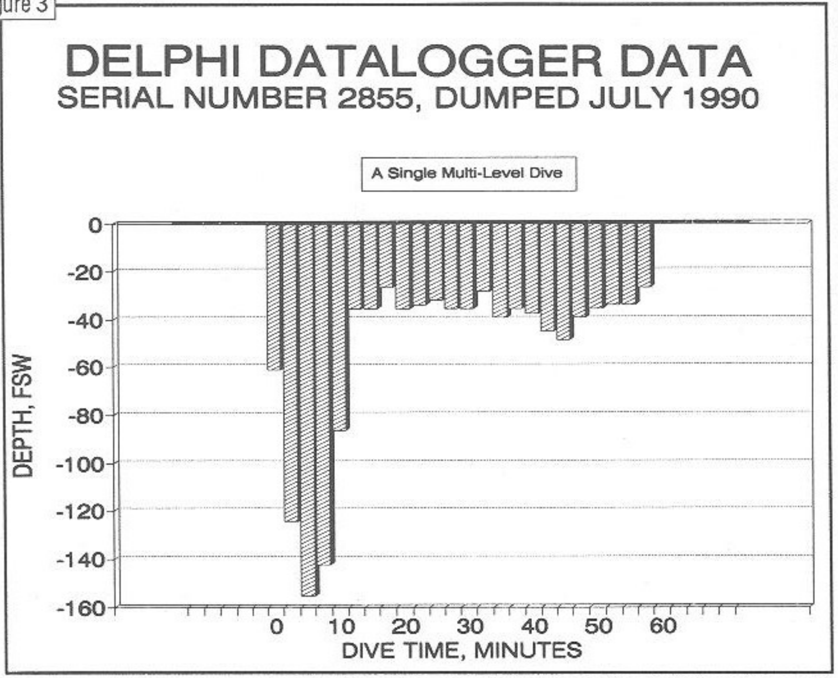


recorded. The DataLogger is accessible through Orca's new **DataReader**, which downloads information from the **Delphi** to an IBM compatible computer. Orca plans recreational diver distribution of the new DataReader in early 1991.

Orca has an ongoing policy to accumulate data from **Delphi** instruments. This data collection is implemented during instrument annual performance checks. When Delphi instruments are returned for these checks, the DataLogger is read into a data bank and the information is summarized for the owner. The information stored in the data bank assists in further research of the human body's reaction to diving, particularly with dive computers *(in this case the Delphi)*. Orca's philosophy is that everyone that owns a Delphi is taking part in this important diving research.

Delphi DataLogger information that is summarized for the Delphi owner is very interesting and educational. This information can be used to change diving habits that lean toward unsafe diving practices. Included in this chapter is a 35 hour dump of a Delphi tested by the author. Figure 6-1 shows the entire contents of the DataLogger memory in graph form. The boxed series of dives in the

Figure 3



center of this graph is a three-dive series and is enlarged in Figure 6-2. This enlarged version breaks down each dive into 2.5 minute increments signified by a bar graph. The first dive of the series *(boxed)* is again enlarged in the next table. Figure 6-3 represents that single multi-level dive dump from the DataLogger. This multi-level dive was made to 157 feet for 60 minutes and is graphically displayed in 2.5 minute increments.

Other information is provided in a summary page that shows the last 10 dives in detail, total number of dives, and a breakdown of specific diving practices for all dives in memory. This breakdown reveals the number of ceilings exceeded, decompression dives, dives with less than 5 minutes residual nitrogen dive time (RNDT), dives with greater than 5 minute RNDT, over-range *(deeper than 200')*, less than 5 minute air limit, lost power during dive, and ascent rate exceeded *(warning ignored)*. The beauty of having such a complete summary is diving practices can be re-evaluated and changed to implement safer techniques.

Chapter 8

A Comparison of Current Computer Features

The confusing mosaic of dive computers available today tends to leave consumers unable to make a decision of which one to buy. There are many variables that need to be considered. These include size, operational parameters, user friendliness, reliability, features, and affordability. Each of these areas will be explained in this chapter.

The size, operational parameters, and features of a dive computer are determined by specifications. User friendliness denotes ease of use and understandability of the computer's features, in other words, how long it takes for the user to get comfortable with all of the features – prior to the dive, during the dive, and after the dive *(including the use of a log feature if available)*, plus the readability of screen information. Reliability is based on how the computers continue to perform and whether or not they malfunction. Affordability can only be determined by the buyer's budget.

Comparing Computers

The dive computer comparisons in this chapter will be approached in two ways. First, each dive computer is reviewed and summarized individually, beginning with a photo of the unit. The summary information contains **Construction, Power Supply, Activation/Deactivation Method, Operational Remarks / Limitations, Features,** and **Price**. Secondly, each dive computer is compared to all of their counterparts in comparison tables throughout this chapter. These tables can be used as quick reference guides and include comparisons of **Operational Limitations, Depth Limitations, Power,** and **Display Features** *(prior to diving, during diving, and after the dive)*.

Testing Criteria

In order to examine user friendliness and reliability, most of the represented 1989 and 1990 model computers were taken on an intensive multi-level, multi-day, multiple-dive study. This consisted of a thirteen-day, 44 dive scrutiny. Elapsed bottom time was over 45 hours and surface interval use time exceeded 30 hours of noting scrolled no-decompression limits, recalling and logging dive profiles, and determining time to fly *(to mention a few)*.

The study was conducted in June 1990, in the warm waters of the Solomon Islands with two days diving Guadalcanal WWII wrecks and eleven days from a liveaboard. The deepest dive was 162' on day ten, the average maximum depth 73', the longest dive an hour and twenty minutes, and the average time spent underwater was an hour and two minutes. All of the computers were put into a decompression dive *(on day five)* to test this function, however, neither ceilings nor ascent rates were violated and no computer was put into an Out of Range (OR) condition during this study. Ascent rates were violated only once on day eight during a shallow dive (36') to test the functionality of ascent warnings. Each of the computer manuals were read at least two times before the tests began.

These dive computers had also been used on single-day multiple and single dives during the previous six months for hundreds of dives. Subsequently, as new dive computers models have become available for testing, test dives were conducted through December 1990.

Categories

Buying a diving computer is a healthy investment, costing between $300.00 and $800.00. How much diving that you do *(or intend to do)* can help justify such an expense. The initial issue of "What type of diving am I going to do?" must be solved to categorize the computer type you want to purchase. We've discussed previously what categories the computers fall into, namely, **Table Based** or the five **Model Based** types. The **Model Based** dive computers consist of the **U.S. Navy Model, Spencer No-D Limits Model, Spencer Limits Rogers Model, Swiss Model**, and the **Reduced Gradient Bubble Model.** These categories are broken down further in Chapter 2.

To simplify the selection process, this section is organized to first inform the consumer about each type of comparison heading. This will provide a brief overview of these headings. Next, each dive computer will be systematically reviewed as per their construction, limitations, features and performance.

Construction

The construction of dive computers encompasses a variety of materials from technologically advanced thermal plastics to plain mineral glass. The cases or housings of the computers are all generally made of one of the newer strong plastics, such as ABS, Lexan, Thermo-plastic or Polyamide plastic. One exception is the Edge, made of machined aluminum *(which is also considered in many circles "bullet proof")*. The display windows are covered or shielded in almost as many different types of materials as the cases, the most common being Lexan. Boots that cover the console units are all made of rubber products. Hose mounts *(a carrying device that contains the dive computer and attaches it to a hose)* are plasticized, hard plastic or of rubber products *(many come in a variety of colors)*. The straps for attaching wrist mount models come in nylon, rubber, or nylon-velcro. All tested adequately.

Dive computers are all manufactured to withstand some abuse *(though we don't advise dropping them from a two story building)*. Some are less likely to malfunction due to abusive handling by the user or the environment. As mentioned earlier, the Edge is "bullet proof". A car could run over one and it would function properly *(we don't recommend this, though)*. All of the units are relatively maintenance free. They should be soaked or rinsed thoroughly in fresh water as a cleaning procedure.

Screen Destruction

All of the construction materials seem to hold up well under normal diving conditions. An area deserving some care is the display screen. These soft LCD screens are subject to two types of destruction, damage caused by abrasion and damage due to direct sunlight.

Several of the dive computers are protected from direct screen abrasion by screen covers. Other dive computers are subject to screen abrasion and should be handled more carefully. This is because the material covering the screen is not very thick and it flexes inward when contact is made with it. St. Claire, a relatively new company, manufacturers screen protectors for each dive computer model available. These screen protectors, called Gage-Gard, are made of non-magnetic stainless steel *(see Dive Computer Accessories later in this chapter).*

All of the computers are also sensitive to being left in direct sunlight for prolonged periods of time. This exposure may cause the screen to black out. In most cases, the screen will return to normal after a period of time, but some loss of contrast may occur.

User Friendliness

The next major consideration in selecting a computer is its "user friendliness". User friendliness refers to how easy it is to use the computer and how long it takes for the user to get comfortable with all of its features. Several areas were examined such as readability of data, screen size, data size, simplicity of data presented, graphic displays, simplicity of graphics, amount of information presented, on/off switching method, convenience in wearing the computer, and overall understandability. The user friendliness will be specifically reviewed for each dive computer.

Readability of Data

Readability is broken down into three basic groups. It is simplest to decipher display information at a quick glance from Group One. Group Two takes more time to read information and is not as user friendly as Group One. Computers in Group Three have the most difficult screens from which to obtain information.

Group One

The easiest computers to read when viewing all of the screen data were Beuchat's **Aladins**, Orca's **Delphi** (*Mares'* **Mentor**) and **SkinnyDipper Mark II**, Oceanic's **DataMax Sport** (*Sherwood's* **Source**), Parkway's **Legend**, Suunto's **SME-ML R-1** and **Solution**, Tekna's **Computek** and U.S. Diver's **Monitors I & II**. These screens were the least confusing to read and information is easily disseminated from any one of them. Dacor's **Micro Brains** are also extremely easy to read graphically, however, numerically some of the information is difficult to discern because of it's tiny size.

Group Two

Oceanic's **DataMaster** series (*and U.S. Diver's* **Data Scans**) are a bit more confusing because of the amount and different types of data displayed in so many different sizes and ways (numerically and graphically). Dacor's **Micro Brains** and Scubapro's **NC-11** and **DC-11** both fall into this grouping when viewed numerically.

Group Three

The least readable computer, technologically the oldest consumer unit (1983) and still one of the most popular, is the **Edge**, using a dot matrix-type LCD screen display. There are several angles where the display data "disappears" from sight due to light refraction. In order to facilitate reading the Edge, it must be turned or angled until the display "re-appears" and the data can be read. The Edge is especially difficult to read during night dives.

Screen Size and Space Usage

Screens vary in shapes and sizes. The shapes are round, rectangular, oval, and hexagon, though most are rectangular. Sizes range from the smallest, Suunto's **SME-MLS**, at 1" wide x 1.25" high to the largest, Tekna's **Computek**, at 2.25" wide x 3.5" high.

The smaller units include Beuchat's **Aladins**, Dacor's **Micro Brains**, Scubapro's **NC-11** and **DC-11**, Suunto's **Solution**, Oceanic's **DataMax Sport** *(and Sherwood's Source)*, and Parkway's **Legend**. The larger units include Orca's **Delphi** and **Edge**, Oceanic's **DataMaster**, and U.S. Diver's **Data Scan** series. The U.S. Divers' **Monitors** and Orca **SkinnyDipper Mark II** *(Sherwood Sigmatech II)* fall somewhere in between.

Unit Size

The smallest, most compact, and lightest units on the market are Dacor's **Micro Brains** and Scubapro's **NC-11** and **DC-11**, however, Beuchat's **Aladins**, Suunto's **SME-MLS** and **Solution**, and Oceanic's DataMax **Sport** *(Sherwood's Source)*, are within .5 an ounce and fractions of an inch. These dive computers have set the trend for future technology to make smaller and lighter more sophisticated units.

Orca's **SkinnyDipper Mark II**, Parkway's **Legend**, and U.S. Divers **Monitors** are in the next grouping. These dive computers are both compact in size *(about the size of a pack of playing cards)* and weigh a mere 6-8 ounces.

Orca's **Delphi** (Mares **Mentor**) step-up into the next size range along with Oceanic's **DataMasters** (and U.S. Diver's **Data Scans**) are nearly equal in size weighing approximately 28 ounces *(1 pound 12 ounces)*. The reason these dive computers are larger and heavier is that they have complete underwater information systems, including air pressure, air consumption, and temperature. **Sigmatech II**'s boot and accompanying pressure gauge makes this unit much larger than it's twin the **SkinnyDipper Mark II** *(almost 3 times thicker)*.

The largest units are Orca's **Edge** and Tekna's **Computek**, weighing in at almost 2 pounds apiece. The Edge is a dive computer only while the Computek is a complete underwater system as explained above.

Placement

There are many options for placement of dive computers. The smaller units may be worn as wrist units, attached to hoses, or carried in a manufacturer console. The wrist mounted dive computer is a nice option for the diver who already owns a pressure/depth gauge combo. Advantages of wrist models over console models include the option of using the dive computer skin diving *(without dragging the console, regulators and hoses along)*, and the ability to continue to use the computer if a high pressure hose is damaged and needs to be replaced. Several models may be attached to a hose with a hose mount. These hose mounts provide little added drag to the diver's equipment. The DataMax Sport also comes as a module that replaces Oceanic's depth gauge modules in their consoles. A special boot is needed to hose mount the Orca units.

Graphic Displays

The dive computers that have graphic displays of no-decompression limits are the **Micro Brains, DataMax Sport** the **Source**, and the **Edge**. The **Computek** uses a graphic display in the form of an icon that shows nitrogen loading. Dive computers with graphic displays of depth are the **SME-MLs**, the **Solution** and the **Edge** *(these include a maximum depth bar)*. The computers with a "Caution Zone" graph are the **DataMasters**, the **DataMax Sport**, the **Source**, and the **Data Scans**. The Data Scans have cylinder pressure bar graphs, while the **Computek** uses an emptying tank to depict air pressure *(called a **Pictograph**)*. Each of these respective graphic displays will be addressed in the following dive computer review.

Power Source

One of the hot topics of dive computer power sources is to be able to change or not change batteries. Battery life of these 24 dive computers range from 200 hours to 8 to 10 years *(manufacturer specifications)*. Dive computer power sources come in three different forms: A user replaceable battery, a factory *(or retailer)* replaceable battery, and permanently installed batteries. Generally, the permanently installed batteries last the longest and the user replaceable batteries have the shortest life span, while the factory replaced batteries fall in a range between them.

User Replaceable

Several of the dive computers have user changeable batteries. These power supplies last from 200 to 1200 hours depending on the type of battery used. The obvious advantage of a user removable power source is being able to install a fresh battery while on an extended dive trip. The disadvantage is that batteries in these types of dive computers do not typically last as long as non-user changeable batteries, the argument being, "If the battery lasts 6 years, there is no need to change it." Another inconvenience is the possibility of shorting out the memory while installing a new battery. This is why some manufacturers elect to replace the new battery at the factory *(or at an authorized dealer in some cases)*.

Factory or Retailer Replaceable

Dive computers with factory replaceable power sources have rather long lasting battery life. The life of these batteries usually lasts from 800 to over 2000 hours of continuous usage. The advantage is not having to change a power supply while on a vacation *(if the battery is relatively new to begin with)* and not inadvertently losing memory from a short circuit or a missed procedure. The drawback is sending the dive computer to the manufacturer *(or going through a retailer)* and hoping it will be returned in a timely manner to make the trip. Estimating how many hours that is left on the remaining battery life can be an inconvenience as well.

Permanently Installed

There are several permanently sealed units. The battery life in these dive computers is expected to be 5 to 8 years with normal use. Defining normal use can vary from manufacturer to manufacturer. Some manufacturers have a dive computer warranty of one or two years and offer an extended warranty *(of three years)* on the batteries. After the warranty period, batteries can be changed for a fee, however, these sealed dive computers are normally considered disposable and the manufacturer will have to provide a new unit in order to replace the battery.

Activation / Deactivation

When testing 24 dive computers side by side it becomes apparent which units are easy to work and which ones present obstacles. Turning on all of the dive computers became almost a ritual as we set up the "super console" for test dives. On a couple of occasions a computer was missed and not turned on, making the test dives for that day useless. How a dive computer is activated is therefore another consideration in deciding its user friendliness.

Activation

Dive computers are separated into one of three different activation methods. There are **manual switches, immersion switches**, and **cylinder pressure activated switches.** Each method allows the dive computer to perform a start-up procedure *(normally a diagnostic check and an atmospheric pressure measurement).* Most of the dive computers have to perform these tests in order to calibrate their transducers at atmospheric pressure to be accurate underwater. Some of the newer units stay active, measuring atmospheric pressure constantly, and are instantly activated. If a dive computer allows a start-up procedure underwater it will display false readings. Thus, it becomes important to know the activation process of your dive computer.

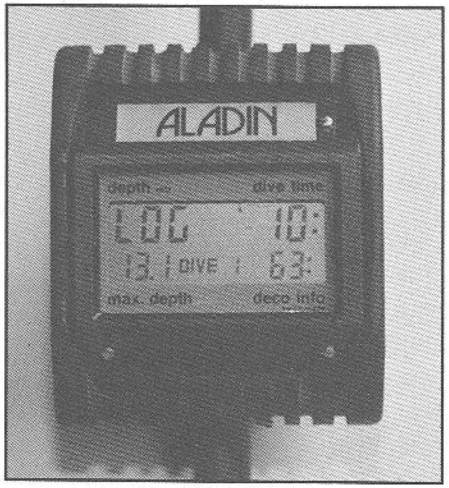
Table 8-1

Dive Computer	Batteries				On / Off Switch	
	Type and Voltage	Number of Batteries	Maximum Life	Replacement	Activation Method	Cancellation Method
Beuchat Aladin	Lithium 3.6 volt	1	800 Dives	Retail Factory	Water Immersion	Desaturation
Beuchat Aladin Sport	Lithium 3.6 volt	1	6 - 7 Years	Retail Factory	Water Immersion	Desaturation
Beuchat Aladin Pro	Lithium 3.6 volt	1	6 - 7 Years	Retail Factory	Water Immersion	Desaturation
Dacor Micro Brain	Lithium 3 volt	2	8 - 10 Years	Factory	Water Immersion	Desaturation/ Magnet
Dacor Micro Brain Pro Plus	Lithium 3 volt	2	8 - 10 Years Rechargeable	Factory	Water Immersion	Desaturation/ Magnet
Mares Mentor	Lithium 9 volt	1	750 Hours	User	Cylinder Pressure	Desaturation
Oceanic DataMaster II	Lithium 3 volt	2	6000 Hours	Factory	Cylinder Pressure	Desaturation
Oceanic DataMaster Sport/S	Lithium 3 volt	2	6000 Hours	Factory	Cylinder Pressure Manual switch	Desaturation
Oceanic DataMax Sport	Lithium 3 volt	2	3 Years	Factory	Manual Switch	Desaturation
Orca Mark II	Lithium 3 volt	3	700 Hours	User	Manual Switch	Switch
Orca Edge	Lithium 9 volt	1	200 Hours	User	Manual Switch	Switch
Orca Delphi	Lithium 9 volt	1	750 Hours	User	Cylinder Pressure	Desaturation
Parkway Legend	Lithium 3.6 volt	1	6 - 7 Years	Retailer Factory	Water Immersion	Desaturation
Scubapro DC-11	Lithium 3 volt	1	2000 Dives Rechargeable	Factory	Water Immersion	Desaturation/ Magnet
Scubapro Dive Vu	Alkaline AA 1.5 volt	2	20 Hours	User	Water Immersion	Desaturation
Sherwood Sigmatech II	Lithium 3 volt	3	700 Hours	User	Manual Switch	Switch
Sherwood Source	Lithium 3 volt	2	3 Years	Factory	Manual Switch	Desaturation
Suunto SME-ML R-1	Silver Oxide 1.5 volt	2	1500 Hours	Retailer Factory	Water Immersion	Desaturation
Suunto Solution	Lithium 3.7 volt	1	2000 Hours	Retailer Factory	Water Immersion	Desaturation
Tekna Computek	Lithium 3 volt	1	1500 Hours	User	Cylinder Pressure	Desaturation
U.S. Divers DataScan 2	Lithium 3 volt	2	6000 Hours	Factory	Cylinder Pressure	Desaturation
U.S. Divers DataScan 3	Lithium 3 volt	2	6000 Hours	Factory	Cylinder Pressure	Desaturation
U.S. Divers Monitor I	Lithium 3.6 volt	1	6 - 7 Years	Retailer Factory	Water Immersion	Desaturation
U.S. Divers Monitor II	Lithium 3.6 volt	1	6 - 7 Years	Retailer Factory	Water Immersion	Desaturation

Dive Computer Overview

Each dive computer has some unique benefits. The major features of each unit are summarized here to help you select which one best meets your diving needs. The dive computers are in alphabetical order by manufacturer *(or distributor)* so that no favoritism is implied. Tables throughout this chapter will aid in comparison of Power Sources, Operational Limitations, and Display Features for each of the computers.

Beuchat's **Aladin**



Beuchat introduced to the United States the original Aladin in 1987 as the **G.U.I.D.E.***(Parkway also introduced their **Black Fox**, the same basic computer, at about this time).* Made by Uwatec of Switzerland, the Aladin became the most popular dive computer in Europe upon introduction, but it had a somewhat slower take-off in the U.S. The Model Based Aladin dive computer is a Swiss Model using Buhlmann's ZHL-12 tables. These Buhlmann tables provide more conservative no-decompression limits than Spencer no-decompression models because of lower M-values in most of the compartments. In practice, this means there is less time at each depth than Spencer No-D Limit model dive computers. There are 6 compartments with a half-time range from 4 to 304 minutes. Depth readouts are in feet of fresh water *(ffw)* or meters of fresh water *(mfw)* and the Aladin is altitude compensated to 13,200 feet. This is considered a no-decompression dive computer with maximum calculations to 330 feet. The Aladin was dropped from retail distribution by Beuchat in mid 1990.

Construction:

The Aladin is made of Lexan Poly carbonate material. The screen is a wide 1 7/8", 3/4" high, and the display face is covered by a clear flexible Lexan film. Care should be taken in protecting this type of screen from heavy abrasion *(See Gage-Gard accessories later in this chapter).*

Power / Activation:

One 3.6 volt lithium battery **powers** the Aladin. The battery must be changed at the factory. Manufacturer estimated life of the battery is 800 hours or 5 years.

To activate the Aladin, it must first be turned on by dipping it in the water or touching the contacts posts with wet fingers, then it has to phase through a start-up procedure for one second, and it is ready to dive. If it is not allowed to go through its start-up procedure, then the Aladin will go into an error display (ERR) throughout the dive. Calculation of time and depth begin after 4 feet.

Features:

- Functional range 330 ffw
- Depth range 330 ffw
- Altitude range 13,200 ft.

- Log book
- Accuracy ±1' (ffw)
- Calculates every 1 second

Before Dive Display
- Error indicator
- Surface power down (Power saving deactivation after 10 minutes)
- Low battery indicator
- High altitude sector
- Log book – 5 dives

During Dive Display
- Current depth
- Maximum depth indicator
- Total elapsed time
- Low battery indicator
- No-decompression time remaining
- Decompression stop depth (10' increments)
- Ascend indicator for decompression

After Dive Display
- Maximum depth (for first 10 minutes only)
- Total dive time (for first 10 minutes only)
- Surface interval

Log Book Features
- 5 dives stored
- Dive number shown
- Dive time
- Maximum depth
- Surface interval

Remarks / Limitations:

1) Activation of the Aladin must be performed correctly or it will go into an error mode.
2) It does not scroll no-decompression limits before the dive. This is irritating when planning subsequent dives because there is no indication of how much time is available for each depth.
3) There is no ascent indicator warning for exceeding the Aladin specified ascent rate that is much slower (33'/min.) than the U.S. Navy 60'/min. rate that most divers are used to.
4) The depth is displayed in units of feet fresh water, not sea water like some dive computers. This is great for fresh water diving (remember the Aladin was developed in Switzerland's fresh water high altitude diving locale), but gives up to a 3% positive error in salt water.
5) The manual provided with the Aladin has instructions showing functions in meters but the computer displays in feet - this can lead the user to confusing important information such as decompression stops.
6) The no-decompression time available during a dive is expressed in a minus number. All other dive computers express time remaining in numbers without signs and decompression stop time is usually shown in minus numbers. (The newer Aladin models do not show minus numbers for time remaining any longer).
7) There is no indication of how much time must be spent at each decompression stop. This dive computer is not recommended for decompression diving.
8) The manual is very small and not very complete.

Software versions:

ZHL-12 *(the Aladin Sport has taken the place of the Aladin)*

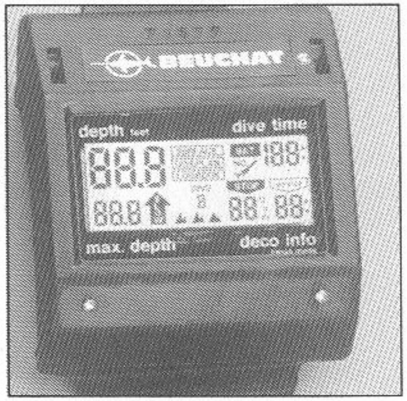
Accessories / Support material:

Dive simulator

Cost / Warranty:

The Aladin comes in wrist, and three console models.
This model Aladin has been discontinued
Warranty: 1 year

Beuchat's **Aladin Sport**



Beuchat's newest model, the Aladin Sport, was introduced in mid 1990 primarily to replace the Aladin. This model has several improved features to give the Aladin Sport less limitations than its little brother the Aladin. Made by Uwatec of Switzerland, the Model Based Aladin Sport uses the newest version of the Buhlmann ZHL-16 Swiss Model. This Model provides more conservative no-decompression limits than other non-Swiss Models like the Edge, which means there is less time limits at each depth. There are 6 compartments with a half-time range from 6 to 320 minutes. The Aladin Sport automatically adjusts to any altitude *(to 13,000 feet)* because it senses atmospheric pressure continuously throughout the life of its batteries. This is considered a no-decompression dive computer.

Construction:

The Aladin Sport is constructed in the same manner as the Aladin. The Aladin is made of Lexan Poly carbonate material. The screen is a wide 1 7/8", 3/4" high, and the display face is covered by a clear flexible Lexan film. Care should be taken in protecting this type of screen from heavy abrasion *(See Gage-Gard accessories later in this chapter).*

Power / Activation

Power to the Aladin Sport is provided by one 3.6 volt lithium battery. The battery must be changed by the factory. Based on a typical dive duration of 45 minutes and desaturation of 10 hours, manufacturer estimated life of the battery is 6-7 years at 50 dives a year, 5 years at 100 dives a year, 2-3 years at 200 dives a year, and 1-2 years at 500 dives per year.

Activation of the Aladin sport is much improved over its predecessor the Aladin. The Sport is completely automated and operates continuously allowing it to adjust to atmospheric changes (including altitude change due to high altitude or flight). Because the Sport is constantly on, activation is achieved instantly upon entering the water or by contacting the posts with wet fingers. Activation depth is 4 feet for calculations.

Features

- Functional range 330 ffw
- Depth range to 330 ffw
- Altitude range to 13,000' (manual's specifications) or 4,000 meters
- Auto Activation - immersion switch (instant on)
- High altitude sector
- Log book
- Dive Plan mode
- Accuracy ±1' ffw
- Calculation every 1 second

Before Dive Displays

- Diagnostic check
- Low battery indicator
- No decompression scrolling 30'-140'
- Surface power down (Power saving deactivation)
- Log book mode

During Dive Display

- Current depth
- Total elapsed time
- No decompression time remaining
- Decompression stop depth
- Ascent rate indicator
- Ascent indicator for decompression
- Tissue type affected in decompression

After Dive Display

- Maximum depth
- Total dive time
- Surface interval time
- Desaturation time
- New no-decompression limits (in Dive Plan mode)

Log Book

- 9 dives stored
- Dive number shown
- Dive time
- Maximum depth
- Surface intervals
- Altitude Sector where dive occurred
- Violation of ascent mode
- Omitted decompression

Remarks / Limitations

1) A much improved version over its predecessor the Aladin, the Aladin Sport has fixed all of the items listed under remarks except there is no time given for decompression stops.

2) There is no total ascent time given. If a decompression profile was indicated, the Sport will not give total time required to the surface nor will it give you the required time at each stop — Not a total decompression dive computer.

3) The manual provided with the Sport shows examples in meters and the computer displays in feet. These inconsistencies could prove confusing (newer manuals may be in feet).

4) The Wait to Fly indicator does not indicate how long to wait before flying. The Sport must be monitored until the no flying icon fades from display.

5) The Aladin Sport must be put in the "DIVE PLAN" mode for it to show no-decompression limits and surface intervals. It does not automatically scroll these limits as other dive computers do.

Software versions:

ZHL-16 updated.

Accessories / Support material

3 console models available

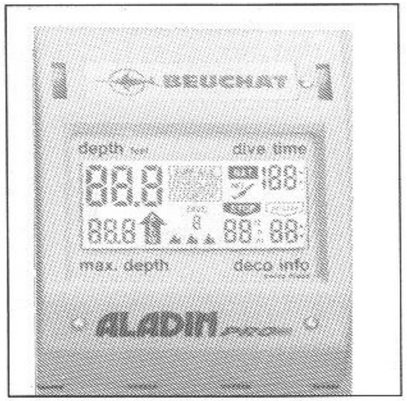
Cost / Warranty:

Wrist	$ 441
Console 1	$ 541
Console 2	$ 577
Console 3	$ 577

Warranty: 12 months

The warranty becomes void if damage is caused by external circumstances or if the unit has been serviced or repaired by third parties unauthorized by Beuchat or their agents. This particularly applies to the replacement of the battery, as an improperly fitted battery can damage the unit. "Dry" pressurizing of the unit will render the warranty void.

Beuchat's **Aladin Pro**



Beuchat introduced their most sophisticated dive computer at the January, 1989 DEMA Trade Show. This is the top-of-the-line Aladin. The Aladin Pro is designed with advanced divers in mind and has several addition features that the Sport doesn't, including waiting time prior to flying, total ascent time, decompression stop time, a phosphorescent screen, and an acoustic alarm for ascent rate or decompression violations. This multi-level Swiss Model dive computer uses the newest version of Buhlmann's ZHL-16 Model and is also manufactured in Switzerland by Uwatec. There is less time at depth because of the more conservative approach of these tables *(see Aladin)*. The Aladin Pro uses 6 compartments with half-time ranges from 6 to 320 minutes.

This is the one of the best high altitude dive computers on the market. The Aladin Pro can be used to altitudes of 13,000 feet as either a desaturated dive computer *(after waiting the appropriate time required by the Pro)* or as a repetitive dive computer at altitude which calculates at a higher saturation level. The Aladin Pro is an advanced dive computer with full decompression and high altitude functions.

Note: The Aladin Pro suspends calculations of tissue desaturation while a decompression stop is violated. If violated, the DECOSTOP display will flash accompanied by the acoustic alarm. This means that it is necessary to descend immediately to the decompression stop.

Construction:

Made of the same Lexan Polycarbonate casing as the other two Beuchat models, the case is identical. The screen should be protected from abrasion in all these models *(see Gage-Gard accessories for screen protectors at end of this chapter)*.

Power / Activation:

Power specifications is identical for all Aladin models; using one 3.6 volt lithium battery. The battery must be changed through the factory. Based on a typical dive duration of 45 minutes and desaturation of 10 hours, manufacturer estimated life of the battery is 6-7 years at 50 dives a year, 5 years at 100 dives a year, 2-3 years at 200 dives a year, and 1-2 years at 500 dives per year.

Activation of the Aladin Pro is immediate with an immersion type switch. The Pro is a "Live" dive computer constantly monitoring atmospheric pressure changes like the Aladin Sport *(see Aladin Sport for more information)*. Activation depth is 4 feet for calculations.

Features:

- Functional range 330 ffw
- Depth range to 330 ffw
- Altitude range to 13,000' (manual's specifications) or 4,000 meters
- Log book
- Dive plan mode - not a simulator
- Accuracy ±1' ffw
- Calculation every 1 second
- Auto activation (immersion switch)
- Luminous phosphorescent screen

Before Dive Displays:
- Diagnostic check
- Low battery indicator

- No decompression scrolling 30'-140'
- Surface power down (Power saving deactivation)
- Logbook mode
- No flying indicator
- High altitude adaptation time
- High altitude sector
- Desaturation time
- Waiting time prior to flying

During Dive Displays:
- Current depth
- Maximum depth
- Total elapsed time
- No decompression time remaining
- Decompression stop depth
- Decompression stop time
- Total ascent time
- Ascent rate indicator
- Acoustic ascent rate alarm
- Ascent indicator for decompression
- Acoustic ascent alarm for decompression
- Tissue type affected in decompression

After Dive Display:
- Maximum depth
- Total dive time
- Surface interval time
- Desaturation time
- No flying icon
- Waiting time prior to flight
- New no-decompression limits (in dive plan mode)

Log Book:
- 9 dives
- Dive number shown
- Dive time
- Maximum depth
- Surface intervals
- Altitude Sector where dive occurred
- Violation of ascent mode
- Omitted decompression

Remarks / Limitations

1) The best of the Aladin line from Beuchat and one of the most sophisticated dive computers on the market. A very good choice for advanced divers.
2) Waiting time prior to flight is calculated to 8,000 feet and tends to be shorter than the current recommendations *(see chapter 10 for recomendations on Flying After Diving)*.
3) A excellent dive computer for high altitude, decompression, or repetitive diving.

Software versions:

ZHL-16 Updated.

Accessories / Support Material:

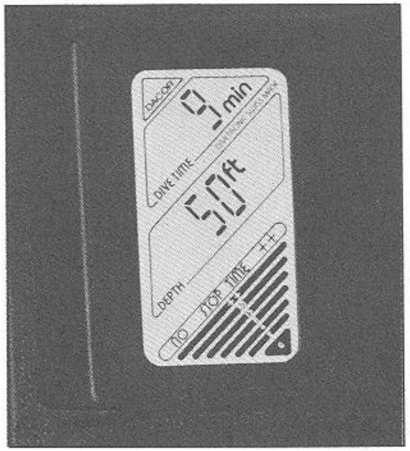
3 console models

Cost/Warranty:

Wrist	$ 628
Console 1	$ 685
Console 2	$ 718
Console 3	$ 718

Warranty: 12 months: Voided if "Dry" pressurized, third party battery replacement, or if damage is caused by external circumstances (same as Aladin Sport).

Dacor's **Micro Brain**



Manufactured by Divetronic AG of Switzerland, who produced the DecoBrain *(see Chapter 1)* in 1983, the Micro Brain is distributed by Dacor Corporation of Illinois. Dacor first introduced the Micro Brain in 1988 as a multifunctional dive computer using a Buhlmann/Hahn (P-3) Swiss Model for calculations. The P-3 version of this Swiss Model was from an abbreviated ZHL-12 Buhlmann Model and has 6 theoretical compartments using half-times from 4 to 397 minutes. The algorithm is compensated for high altitude dives *(and this compensation applies to all dives up to 4,920 feet)* by using a reduced surface atmospheric pressure of 12.7 p.s.i. for its calculations instead of using 14.7 p.s.i. or 1 atmosphere that all other dive computers use. This built-in altitude compensation results in more conservative no-decompression limits *(more conservative than most other models except the Tekna Computek and Scubapro DC-11)* and allows its user to perform high altitude dives up to 4,920 feet without a waiting period. High altitude profiles to 6,560 feet can be accomplished after equilibration to ambient pressure. The Micro Brain functions as a bottom timer and altitude compensating depth gauge from 6,560 feet to 19,685 feet, its maximum reading range.

The Micro Brain *(and Micro Brain Pro Plus)* is unique for having the only graphic display of no-decompression limits in a dive computer. The graphic representation of no-decompression limits is shown in a contracting and expanding triangle made from bars representing each no-decompression limit range *(see sidebar Micro Brain's Triangle, page 97)*. The Micro Brain is also equipped with a dive log recall, which can recall previous dives. This recall shows the total underwater time and the maximum depth of the previous 6 dives in up to 48 hours.

Construction:

A potted case made from glass reinforced polyamide plastic hermetically sealed in silicone gel holds the entire contents of this 3.5 ounce dive computer. The screen is 1 3/4" wide x 1" high covered by a thin film of Lexan giving cause to avoid screen abrasion or abuse *(See Gage-Gard accessories)*.

Power / Activation:

Two 3 volt lithium batteries **power** the Micro Brain for a manufacturer estimated life of 8-10 years based on 100 dives per year. The batteries must be factory replaced, however, the Micro Brain has a five year battery warranty.

Activation of the Micro Brain is by an immersion switch, which renders the computer functional after a start-up. The start-up screen takes about 5 seconds and must be allowed to run or the Micro Brain will not read underwater. Power saving deactivation occurs after about 4 minutes of non-use and the Micro Brain must be re-started before directly descending on a dive.

A magnetic reed switch is built into the case for deactivation or manual clearing with an external magnet *(one is provided with the computer)*. Activation depth is 5 feet for calculations.

Features:

- Functional Range to 270'
- Depth reading capacity to 330'
- Altitude range to 6,560'

- Log book (holds memory for up to 48 hours)
- Accuracy ±1'
- Calculation every 5 seconds (depth every 1 second)
- Available in feet or meter depth display

Before Dive Displays:
- Diagnostic check
- Software version
- No decompression scrolling 51'-130'
- Surface power down (Power saving deactivation after 4 minutes)
- Log book mode

During Dive Displays:
- Current depth
- Total elapsed time
- No decompression time remaining (graphic)
- Decompression stop depth (up to 98')
- Ascent rate indicator
- Ascent indicator for decompression
- Descent warning for ceiling violation
- Out of range - omitted decompression

After Dive Display:
- Maximum depth
- Total dive time
- Do not fly indicator to equivalent altitudes of 8,000'
- New no-decompression limits (in dive plan)

Log Book:
- Up to 6 dives
- Dive time
- Maximum depth

Remarks/Limitations

1) Activation of the Micro Brain must be performed properly or it will not read correctly underwater. The start-up process takes about 5 seconds. It also deactivates after about 4 minutes and must be re-started and put into the dive mode before using underwater.

2) The size is very convenient, and Micro Brains have the greatest number of options to choose where to wear them *(wrist, hose mount, console)*.

3) Corrosion of the activation pins is a frequent problem in older models of the Micro Brain. This condition can cause no activation *(or improper activation)* of the dive computer and may not be noticed until after the dive is started. To prevent this condition, clean the activation pins by wiping them with a cloth until they are bright again. All later models were gold-plated throughout the circuit and this problem does not occur.

4) The amount of no-decompression time remaining is not given numerically, it is given graphically *(see Micro Brain Triangle sidebar on page 97)*. The advantage of this is a quick glance at the triangle will show its size, which determines approximately how much no-decompression time is remaining – the larger the triangle the greater amount of time remains *(and the smaller the triangle the less amount of time remains)*. The disadvantage is that the exact amount of time is not shown as a real number – only a range of no-decompression limits is given within the triangle and this range of numbers are so small they cannot be read easily. The user must be familiar with this function of the Micro Brain to avoid confusion while diving this computer. Dacor indicates that the display is meant to be read graphically.

5) The **"Ascend"** warning indicator is used in an ambiguous manner. First, it is used as a warning for ascending too fast. If the Micro Brain's ascent rate of 33-40 feet per minute is exceeded, the **"Ascend"** warning indicator flashes at you, meaning to slow down, you are ascending too fast. Other dive computers use warnings such as **"Slow"** or **"Ascend Slower"** which are more appropriate and clearly understood by the user. Secondly, the same **"Ascend"** warning is used to indicate that decompression is required and you must ascend to the Deco Stop. These two separate uses with the same warning makes it possible for the user to confuse which procedure to follow. This is an excellent example of why manuals must be read and fully understood before diving a dive computer.

6) There is no time given for decompression stops – decompression stops run in 10' increments and are controlled by a ceiling or safe ascent depth range. The problem here is that you have no idea of how much air you are going to use at the stop because the time for each stop is not given.
7) When using the Micro Brain at high altitudes above 4,920 feet, you must wait for equalization to the ambient pressure at the new altitude to allow the human body to acclimate itself.

Software versions:

P-3

Accessories / Support Material:

Accessories are a hose mount kit and a belt pouch or console bag.
Support materials include an Atari computer program, dive simulator model, and dive computer comparison charts.

Cost/Warranty:

Micro Brains came as wrist, slip-on, and console models:
This dive computer was discontinued in 1991

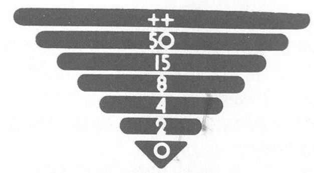
Warranty: 2 Years; Batteries 3 additional Years: This warranty is non-transferable and is limited to repair or replacement of defective parts at Dacor's option. This warranty does not extend to breaking or scratching of the lens or to the attaching straps or fasteners.

Dacor's **Micro Brain Pro Plus**

Distributed by Dacor in the U.S. since early 1989, the Micro Brain Pro Plus, is one of the most sophisticated full decompression computers available with 36 different functions and is a great improvement over the Micro Brain. Made by Divetronic AG, it is a multi-functional dive computer using a Buhlmann/Hahn (P-4) Swiss Model for calculations which makes this computer more conservative than the U.S. Navy Tables and just a shade more conservative than the Uwatec models. The P-4 is an up-dated version of the Swiss Model originating from an abbreviated ZHL-12 Buhlmann Model. The Micro Brain Pro Plus has 6 theoretical compartments using half-times ranging from 6 to 600 minutes which differ from its predecessor the Micro Brain.

The Pro Plus' algorithm is compensated in the same manner as the Micro Brain's for high altitude dives *(and this compensation applies to all dives up to 4,920 feet)* by using a reduced surface atmospheric pressure of 12.7 p.s.i. for its calculations instead of using 14.7 p.s.i. or 1 atmosphere that all other dive computers use. High altitude profiles to 6,560 feet can be accomplished after equilibration to ambient pressure. The Micro Brain Pro Plus functions as a dive timer and altitude compensating depth gauge from 6,560 feet to 14,764 feet, its maximum range.

Micro Brain's Triangle



The Micro Brain's graphic display is a series of bars of ascending lengths forming a triangle. This triangle area is located in the lower left-hand part of the screen. Each of the bars making up this triangle represent a level of the no-decompression limit remaining. Note that this graphic display does not represent theoretical nitrogen absorption within the tissues, where as the Edge's display does. The upper bar, ++, means the time remaining is greater than 30 minutes, and the lowest bar, 0, means that there is less than one minute remaining before decompression is required. The triangle ascends by these bars from 0 to 2, 4, 8, 15, 30, and ++. The deeper and longer a diver descends, the smaller the triangle becomes. Rather than giving no-decompression limits as a numeric value, the Micro Brain gives a range that falls within these 7 bars making up the triangle. For example, visualize the first four bars, the 0, 2, 4, and 8, making up the smaller triangle that it would. This indicates that the diver has less than 8 minutes and more than four minutes. Graphically, this is a simple method because as long as there is a triangle, the user is within the no-decompression limits. The larger the triangle becomes, the greater the time is allowed underwater, and conversely, the smaller the triangle becomes the shorter the time allowed. The smallest triangle (0) provides the user a graphic warning signal just before the remaining no-decompression time has expired. This graphic warning consists of this small 0 triangle flashing on and off giving a good visual indication that no-decompression time is gone and you are entering a decompression dive within the minute.

The time ranges of the bars lends to interpolation underwater by the user rather than giving specific no-decompression time limits. To illustrate, the start-up no-decompression limits for 70, 80 and 90 feet respectively are all 30 minutes, or somewhere between 30 and 15 minutes. The user then either decides where the no-decompression limit falls, or just uses the triangle as a graphic reference. The numbers that are associated within these bars are very difficult to read because of their small size, but they could be easily memorized.

The Micro Brain Pro Plus was the first dive computer with a built-in simulator that allowed real time simulation of dive profiles. The Pro Plus will handle decompression diving unlike the simpler Micro Brain. Large numbers flash the depth of the first decompression stop and ascent time. Other special features include Logbook Memory, a Dive Recorder and a Dive Planner. The Micro Brain Pro Plus is another advanced dive computer with 36 different functions, yet graphically, one of the simplest units to use.

Construction:

The Pro Plus is made of the same case as the Micro Brain and it comes in five colors. The case is made from glass reinforced polyamide plastic hermetically sealed in silicone gel and it holds the entire contents of this 3.5 ounce dive computer. The screen is 1 3/4" wide x 1" high covered by a thin film of Lexan giving cause to avoid screen abrasion or abuse
(See Gage-Gard accessories).

Power / Activation:

Two rechargeable 3 volt lithium batteries **power** the Micro Brain. Proper recharging can prolong battery life of the Pro Plus for about 6 years independent of the number of dives. Battery life without recharging for dives of one hour plus an average of 12 hours of desaturation time is approximately 1500 in 1-2 years, 1000 dives in 5-7 years, and 500 dives in 10-12 years. The batteries can be charged through the external activation contacts with a compact battery powered charger for up to 6 full re-charges. The batteries must be factory replaced.

Activation of the Micro Brain Pro Plus is by an immersion switch, which turns the Pro Plus on after a start-up. The start-up screen takes about 5 seconds and must be allowed to run or the Pro Plus will not read correctly underwater (this is self-correcting upon surfacing the unit). Power saving deactivation occurs after about 4 minutes of non-use and the Pro Plus must be re-started before directly descending on a dive. A magnetic reed switch is built into the case for deactivation or manual clearing with an external magnet *(one is provided with the computer)*. Activation depth is 5 feet for calculations.

Features:

- Functional Range to 270'
- Depth reading capacity to 330'
- Altitude range to 6,560'
- Log book (last 6 dive until desaturation, then last 3 dives)
- Dive Recorder (total number of dives, total hours, maximum depth ever)
- Dive Planner (to 270', up to 199 min., deco times up to 90 min., deco stops to 78')
- Accuracy ±1'
- Calculation every 5 seconds (depth every 1 second)
- Available in feet or meter depth display

Before Dive Displays:

- Diagnostic check
- Software version
- No decompression scrolling 41'-149'
- Surface power down (Power saving deactivation)
- Log book mode
- Dive recorder
- Dive planner

During Dive Displays:

- Current depth
- Total elapsed time
- No decompression time remaining (graphic)
- Decompression stop depth (up to 78 feet)
- Total ascent time (up to 90 minutes)
- Ascent rate indicator
- Descent warning for ceiling violation
- Ascent indicator for decompression
- Out of range - omitted decompression

After Dive Display:

- Maximum depth (in log book mode)
- Total dive time
- Surface Intervals (in log book mode)
- Do not fly indicator to equivalent altitudes of 8,000'
- Time to fly
- New no-decompression limits
- Desaturation time
- Dive plan
- Dive recorder

Log Book:

- 3 dives stored (last 6 dive until desaturation, then last 3 dives)
- Dive time

- Dive number
- Surface Intervals
- Maximum depth

Remarks/Limitations

1) Activation of the Micro Brain Pro Plus must be performed properly or it will not read correctly underwater. The start-up process takes about 5 seconds. It also deactivates after about 4 minutes and must be re-started before using underwater in a dive mode.

2) We have not detected the activation pins corrosion as a problem. This seems to have been rectified and is only found in older models of the Micro Brain *(See Micro Brain – Limitations)*.

3) The amount of no-decompression time remaining is not given numerically, it is given graphically *(see Micro Brain Triangle sidebar on page 97)*. The advantage of this is a quick glance at the triangle will show its size, which determines approximately how much no-decompression time is remaining, the disadvantage is that the exact amount of time is not shown as a real number *(see Micro Brain Limitations for more)*. Dacor indicates that the display is meant to be read graphically.

4) The **"Ascend"** warning indicator is a little less ambiguous than in the plain Micro Brain because it doesn't serve in dual functions. It is, however, still used in a confusing manner when exceeding the computer ascent rate. If the Micro Brain Pro Plus' ascent rate of 33-40 feet per minute is exceeded, the **"Ascend"** warning indicator flashes at you, meaning to slow down, you are ascending too fast. Other dive computers use warnings such as **"Slow"** or **"Ascend Slower"** which are more appropriate and clearly understood by the user.

5) Time is now given for decompression stops as total ascent time – decompression stops run in 10' increments and are controlled by a ceiling or safe ascent depth range. This is much improved over the Micro Brain and qualifies as a true decompression dive computer.

6) When using the Micro Brain Pro Plus at high altitudes above 4,920 feet, you must wait for equalization to the ambient pressure at the new altitude to allow the human body to acclimate itself.

7) A low battery indicator or amount of remaining battery life would be desirable for the Pro Plus to help the user decide when to charge the batteries.

8) The size of the manual (8 1/2" X 11") is not a convenient size to fit into dry boxes or pouches.

9) Micro Brains are the smallest of dive computers and have the greatest number of options to choose where to wear them *(wrist, hose mount, console)*.

Software versions:

P-4

Accessories / Support Material:

Accessories are a hose mount kit, autonomous battery recharger kit, a 5 station recharger (with current converter), and a belt pouch or console bag.

Support material includes dive computer comparison charts.

Cost/Warranty:

Wrist	$625
Slip-on	$625
Console	$730

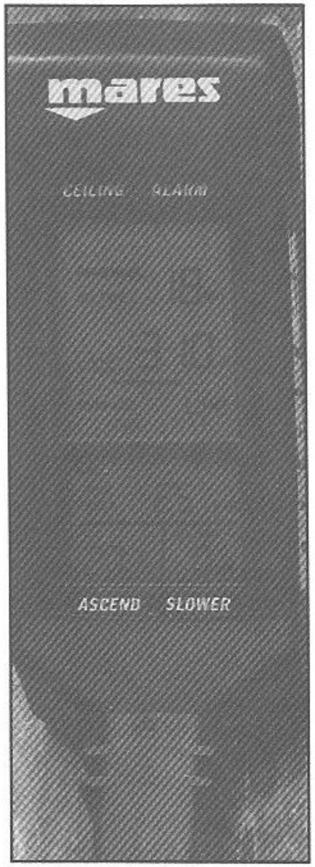
Warranty: 2 Years: This warranty is non-transferable and is limited to repair or replacement of defective parts at Dacor's option. This warranty does not extend to breaking or scratching of the lens or to the attaching straps or fasteners nor does the warranty extend to fragile internal parts such as crystals and reed switches damaged by shock or other abuse. Also excluded from coverage are defects resulting from chemical of electro-chemical influence or resulting from tampering or repair by non-authorized personnel. The battery are excluded from this warranty.

Battery Warranty: Dacor warrants the battery used in the Micro Brain Pro Plus for a period of one year from date of first use unless improper charging methods have been utilized or user has failed to charge the unit frequently enough to maintain a proper level of voltage.

Mares' **Mentor**

Made for Mares by Orca, the Mentor was introduced in 1990 and is the same dive computer as the Delphi without the tissue bar at the top. This dive computer is a total information package which not only performs time and depth calculations that determine no-decompression and decompression status, it includes air pressure, air consumption, and temperature. This system is about the same size as any other gauge console combo and is attached to a regulator by a high pressure hose.

The Mares Mentor is a full decompression Model Based dive computer using the Spencer No-D Limits for calculations. This model is slightly more conservative than the U.S. Navy tables, but not as conservative as the Swiss Models. The Mentor has 12 theoretical compartments using half-times ranging from 5 to 480 minutes. This is the algorithm originally developed by Karl Huggins and Craig Barshinger that was used in the Orca Edge. The Mentor has a depth range to 200 feet and a 10,000 feet altitude capability.



Construction:

The Mentor case is made of high impact reinforced Lexan plastic and is covered in a rubberized boot for extra protection. The display screen is protected with a scratch resistant coated Lexan and is recessed in the case about 1/4". This extra covering of Lexan over the display screen helps protect it from damage due to abrasion or abuse.

Power / Activation:

One replaceable 9 volt lithium battery powers the Mentor for a manufacturer estimated life of 750+ hours of continuous use (or about 1 month of continuous operation). Alkaline batteries are estimated to last one week. Rechargeable batteries are not recommended for use in the Mentor because they will give little or no low battery warning before power loss. The batteries can be changed through an external screw-in battery compartment that is sealed by an O-ring. When replacing a battery, you have 30 seconds to make the change without endangering the computer's memory. After the battery has been properly installed, the mentor will start-up after 45 seconds showing the current battery voltage. (See sidebar **Reading the battery voltage window**, page 105)

Activation of the Mentor is by a pressure activated switch, which runs the computer through a start-up sequence that checks all functions. A minimum of 250 p.s.i. cylinder pressure is need to activated the Mentor's switch. The start-up screen takes 45 seconds to establish surface reference pressure and this allows you to check all of the functions. Power saving deactivation occurs either after 30 minutes of surface wait time before the first dive or residual nitrogen is not a factor to subsequent dives. Activation depth is 6.1 feet for starting time and depth calculations.

Features:

- Functional Range to 199'
- Depth reading capacity to 199'
- Altitude range to 10,000'
- Log book (last 3 dives, and last 35 hours internally stored)

Reading the battery voltage window

The Delphi and Mentor initially read battery voltage upon start-up. Battery voltage is indicated by the number in the cylinder pressure display window and by a bar graph. This battery voltage display window replaces the tank PSI window with a BAT indication. A new battery shows a numeric voltage reading above 9.00 and the computers shut down when the voltage drops below 6.40. The bar graph, made up of 10 segments, reads full at 10.00 and empty at 5.00 volts. Each of the bar's segments represents .5 volts.

Voltage	Display	Life	Operation
Over 9.00	normal	750+ Hrs	normal
7.40 - 8.00	Lo	75+ Hrs	normal
7.00 - 7.30	Lo Lo	15+ Hrs	No lights
6.50 - 6.90	Lo Lo Lo	3+ Hrs	Don't Dive!
Under 6.40	Lo Lo Lo Lo	0 Hrs	Shut down

- Cylinder pressure (up to 5,000 p.s.i.)
- Remaining air time
- Temperature
- Accuracy ±1.5'
- Calculation every 3 second
- Available in feet or meter depth display

Before Dive Displays:
- Diagnostic check
- Software version
- Remaining power
- Low battery warning
- No decompression scrolling 30'-130'
- Surface power down (Power saving deactivation)
- Log book mode

During Dive Displays:
- Current depth
- Total elapsed time
- No decompression time remaining (digital)
- Decompression stop depth (ceiling)
- Total ascent time
- Ascent rate indicator
- Ascent indicator for decompression
- Out of range - depth
- Cylinder pressure
- Remaining air time
- Temperature

After Dive Display:
- Maximum depth
- Total dive time
- Surface Intervals
- Waiting time prior to flight
- New no-decompression limits
- Cylinder pressure
- Temperature

Log Book:
- 3 dives stored
- Dive time
- Dive number
- Surface Intervals
- Maximum depth
- Dive profiles (up to 35 hours at 2.5 minute increments – factory)

Remarks / Limitations

1) One limiting factor of the Mentor *(to a small percent of professional divers)* is the depth range of 199 feet *(though we do not advise going to depths deeper than 130 feet)* for advanced users. The Mentor will go into an "Out of Range" mode (**"OR"**) at 199 feet and continue this display every 3 seconds until the unit is turned off at the surface. The problem here is there will be no readout of the depth after 199 feet.

2) The power source is another limitation. The recommended power source for the Mentor is a Kodak Ultralife 9 volt Lithium cell battery. Kodak quit manufacturing this battery for a period of time in 1990, but they have now decided to continue its manufacture. Mares estimates battery life to be 750+ continuous hours before reaching the "Lo" indication. At that time, the Mentor will function another 75 hours before reaching the "Lo Lo" indication, leaving 15 hours before the battery must be changed. We found in our testing that the battery failed within 40 hours of reaching a "Lo" indication and within only 2 to 4 hours of reaching a "Lo Lo" indication. The apparent problem is with the Lithium battery which appears to have a much faster voltage drop-off rate than expected by the manufacturer. We also found that cold weather top side made the battery drop significant voltage. Our recommendation is to change the battery soon (within 10 hours) of reaching a "Lo" battery indication.

3) You must remember to turn on the Mentor at the surface and the computer has to perform its pre-dive start-up before diving it. For those in the habit of turning their air on at the water's surface, this dive computer must be held in the air for about 45 seconds.

4) The Air Limit, which is read in minutes, zeros out at 500 p.s.i. This is can be annoying because divemasters tend to freak-out when they see *(or think they see)* you're out of air. Actually, this is an additional safety factor built in by the manufacturer.

5) High altitudes diving with the Mentor is to 10,000 feet. At altitudes between 2,000, to 10,000 feet you must wait for equalization *(48 hours)* to the ambient pressure at the new altitude or the Mentor can give false decompression readings. There is a special initialization process if you don't have time to acclimate at altitude. First, turn on the Mentor at your initial altitude, then just before entering the high altitude lake, reset the Mentor's surface reference by removing the tank air pressure (turning off the tank and bleeding the regulator) for 5 minutes. The Mentor will now make proper calculations for the new altitude.

6) Certain failures of this unit (power failure, electronic) would not allow you to dive with a submersible pressure gauge.

7) As of this writing, the DataLogger (dive profile recall) is only accessible by sending the Mentor back to the manufacturer for data output. Mares (or Orca) will have a data reader for the consumer market in early 1991.

8) There is a recall on software version 3.0 in serial numbers ranging from 6500 to 8785 (and some lower numbers). To verify the 3.0 version number, simply turn the computer on and wait for the second display screen to appear. The depth display area in the center will show the software version. **Version 3.0 should not be used for decompression diving.**

Software versions:

1.0	10-89	Original
3.0	06-90	Improved Low Battery Detection
4.0	12-90	Improved decompression software, Phosphorescence screen display, and modified battery door to hold the battery from moving.

Accessories / Support Material:

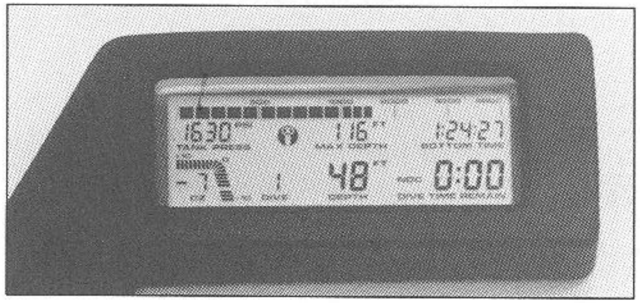
No accessories at this time
Support material: manual, simulator

Cost/Warranty:

Console $ 680

Warranty: 2 Years: This limited warranty shall apply only to the original Buyer of the instrument, and shall not be effective with respect to instruments which have been used in rental, sharing, or similar multi-user arrangements.

Oceanic's **DataMaster II** (Discontinued; see DataMaster Sport for photo)
U.S. Divers' **Data Scan 2** (Discontinued)



U.S. Divers Data Scan 2

Through a cooperative effort between Oceanic U.S.A. and U.S. Divers, the DataMaster II and Data Scan 2 were developed and introduced in 1987 *(see Chapter 1, **History and Development of Dive Computers**)*. It was Pelagic Pressure Systems, an Oceanic subsidiary company, that conducted the research and development of these dive computers. Dr. John Lewis used and, like the U.S. Navy Tables, based off-gassing on the 120 minute compartment for the computer's algorithms. Both computers use 6 compartments with half-times the same as the U.S. Navy's, ranging from 5 to 120 minutes.

These dive computers were combined total information units that included electronic cylinder pressure. All dive information is packaged into one display face, and the DataMaster II even displays temperature. Information contained on the display prior to diving includes a diagnostic check, low battery warning indicator, scrolling of depth and no-decompression limits, and cylinder pressure. Displayed during the dive is a digital depth gauge, the air time remaining or the no-decompression time remaining, an out of range error if the user goes too deep, a warning for exceeding no-decompression limits, the decompression stop time, the decompression stop depth, temperature gauge, and the time remaining based on air consumption rate. The surface mode displays surface interval time, maximum depth, total underwater time, and scrolling of depth and no-decompression limits. Extra features include a caution zone graphic display, cylinder pressure displayed both numerically and graphically, and repetitive group letters.

Both the DataMaster II and the Data Scan 2 have been discontinued and are no longer distributed by Oceanic or U.S. Divers. These dive computers have been replaced by different hardware and software versions *(See Data Scan 3, DataMaster Sport)*.

Construction:

The case back for these dive computers is made of nylon/glass filled Noryl and is covered in a Neoprene boot for extra protection. The display screen is protected with a Lexan polycarbonate resin that is scratch resistant and is recessed in the case about 1/4". This extra covering of Lexan over the display screen helps protect it from damage due to abrasion or abuse.

Power / Activation:

Two replaceable 3 volt lithium long life batteries power these dive computers for a manufacturer estimated life of 6,000 hours over 300 diving days. Shelf life of the batteries is expected to be in excess of 3 years. Low battery display with give approximately 900 hours *(about 45 days)* of use. Battery replacement is through the factory, and a cost estimate can be obtained from an authorized Oceanic or U.S. Divers dealer.

Activation is by a pressure activated switch, which runs the computer through a start-up sequence that checks all functions. A minimum of 50 p.s.i. cylinder pressure is needed to activate the computers. The start-up screen takes 15 seconds to establish surface reference pressure. Activation depth is 7 feet for starting time and depth calculations.

Features:

- Functional Range to 138'
- Depth reading capacity to 249'
- Altitude range to 2,000'
- Cylinder pressure (up to 4,000 p.s.i.)
- Air time or no-decompression time remaining
- Repetitive Group letter
- Temperature (for Oceanic models)
- Accuracy + 1%, - 0%
- Calculation every 1 second
- Available in feet or meter depth display

Before Dive Displays:
- Diagnostic check
- Low battery warning
- No decompression scrolling 30'-130'

During Dive Displays:
- Current depth
- Maximum depth
- Total elapsed time
- Dive number
- No decompression time remaining (digital and graphic - last 10 minutes)
- Decompression stop time (up to 10 minutes)
- Out of range - depth, more than 10 min. decompression stop
- Cylinder pressure (digital and graphic)
- Remaining air time or no stop time
- Temperature (Oceanic only)

After Dive Display:
- Maximum depth
- Total dive time
- Surface Intervals
- Dive number
- New no-decompression limits
- Cylinder pressure – digital (and graphic on U.S. Divers)
- Temperature
- Repetitive group letters

Remarks / Limitations

1) The amount of information in the screen is so great that ergonomically these dive computers are less user friendly when viewing their display than when viewing other models.
2) The 120 minute half-time is used in surface out-gassing calculations for all compartments in these two dive computers. This leads to long surface interval time between dives.
3) The power source must be replace at the factory which means giving up your entire gauge package for a period of time when new batteries come due. To date, we have not had to replace batteries in these dive computers which have been used for almost 3 years. Oceanic and U.S. Divers both estimate a 2 to 3 week time period *(starting when they receive them from the dealer)* to change batteries in these computers and return them.
4) The major limiting factor of these dive computers is way they function with respect to decompression diving. The manual states: "The DataMaster II (Data Scan 2) IS NOT a decompression meter. Although it will aid you in the event you inadvertently exceed the no-decompression limits, Oceanic USA (U.S. Divers) does not advocate this type of diving." The capacity for decompression is limited to 10 minutes total decompression time between 10 and 12 feet. These dive computers will not provide decompression information beyond those limits.

5) If these dive computers are put into a violation mode, they will not function as a dive computer on subsequent dives for 12 hours after the violation. Violations include exceeding 138 feet, leaving the "window" of a decompression stop for more than 10 seconds (the window is between 10 and 12 feet), not decompressing according to the computer's instructions, or exceeding 10 minutes of decompression stop time. The only display functions that are supplied after a violation mode are tank pressure, depth, maximum depth, dive time, surface time, dive number and temperature. The Caution Zone screen also completely blanks out 60 seconds after the violation.
6) High altitude diving with these dive computers is only to 2,000 feet. Above 2,000, these dive computers will not give decompression or air time remaining information. They will function as a tank pressure, depth, maximum depth, bottom time, surface time, dive number and temperature gauge up to 10,000 feet.
7) A failure of this unit (power failure, electronic) would not allow you to dive with a submersible pressure gauge.

Software versions:

DataMaster II / Data Scan 2 Original

Accessories / Support Material:

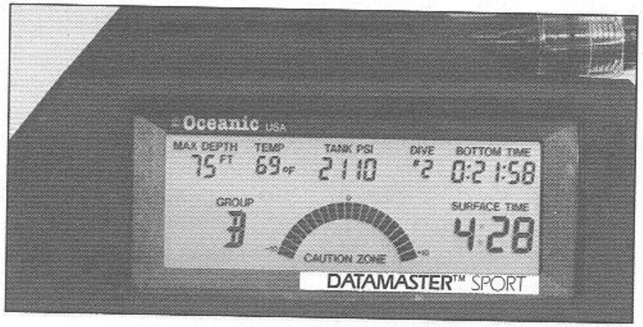
A dive light is an accessory on the DataMaster II, or an optional compass (not both)
Support material includes manual, simulator

Cost/Warranty:

Console: These models have been discontinued

Warranty: 2 Years with annual maintenance: This warranty specifically does not apply to plastic gauge faces, rubber boots, HP hoses, batteries, damage due to accident or abuse, modification, or tampering. Warranty is non-transferable and applies to original owner only.

Oceanic's **DataMaster Sport – DataMaster Sport/S** U.S. Divers' **Data Scan 3**



Oceanic DataMaster Sport

It was Pelagic Pressure Systems that conducted the research and development of the next wave of dive computers for Oceanic and U.S. Divers. Dr. John Lewis used new research from Dr. Michael Powell's study *(see **Other Sport Diving Tables**, Chapter 4)* based on a 60 minute compartment off-gassing for these computer's algorithms. Both computers use 6 compartments with half-times ranging from 5 to 120 minutes.

Extra features include an ascent rate indicator, a caution zone graphic display, cylinder pressure displayed both numerically and graphically, and repetitive group letters. The Sport does not shut down computer functions as quickly after either a decompression dive or a dive that exceeds the depth range like DataMaster II and Data Scan 2 computers.

Oceanic replaced the DataMaster Sport model with the **DataMaster Sport/S** in early 1990, which was up-graded with an additional on-switch to turn the computer on without air pressure. U.S. Divers replaced their Data Scan 2 with the **Data Scan 3** and added the same switch.

Construction:

The case back for these dive computers is made of nylon/glass filled Noryl and is covered in a Neoprene boot for extra protection. The display screen is protected with a Lexan polycarbonate resin that is scratch resistant and is recessed in the case about 1/4". This extra covering of Lexan over the display screen helps protect it from damage due to abrasion or abuse.

Power / Activation:

Two replaceable 3 volt lithium long life batteries power these dive computers for a manufacturer estimated life of 6,000 hours over 300 diving days. Shelf life of the batteries is expected to be in excess of 3 years. Low battery display with give approximately 900 hours *(about 45 days)* of use. Battery replacement is through the factory, and a cost estimate can be obtained from an authorized Oceanic or U.S. Divers dealer.

Activation is by a pressure activated switch, which runs the computer through a start-up sequence that checks all functions. A minimum of 50 p.s.i. cylinder pressure is needed to activate the computers. The DataMaster Sport/S also has a manual switch. The start-up screen takes 15 seconds to establish surfacer reference pressure. Activation depth is 7 feet for starting time and depth calculations.

Features:

- Functional Range to 167'
- Depth reading capacity to 249'
- Altitude range to 2,000'
- Cylinder pressure (up to 4,000 p.s.i.)
- Remaining air time
- Temperature (for Oceanic models)
- Accuracy +1%, - 0%
- Calculation every 1 second
- Available in feet or meter depth display

Before Dive Displays:

- Diagnostic check
- Low battery warning
- No decompression scrolling 30'-160'

During Dive Displays:

- Current depth
- Maximum depth
- Total elapsed time
- Dive number
- Ascent rate warning indicator
- No decompression time remaining (digital and graphic last 10 minutes)
- Decompression stop time (up to 10 minutes)
- Out of range - depth, and more than 10 min. decompression time
- Cylinder pressure – digital (and graphic in U.S. Divers)
- Remaining air time
- Temperature (Oceanic only)

After Dive Display:

- Maximum depth

- Total dive time
- Surface Intervals
- Dive number
- New no-decompression limits
- Cylinder pressure – digital (and graphic in U.S. Divers)
- Temperature (Oceanic)

Remarks / Limitations

1) The amount of information in the screen is the same as the older model and is so great that ergonomically these dive computers are less user friendly when viewing their display than when viewing other models.

2) The power source must be replace at the factory which means giving up your entire gauge package for a period of time when new batteries come due. To date, we have not had to replace batteries in these dive computers which have been used for almost 2 years. Oceanic and U.S. Divers both estimate a 2 to 3 week time period *(starting when they receive them from the dealer)* to change batteries in these computers and return them.

3) A 60 minute half-time is used in surface out-gassing calculations for all compartments (except those equal to or faster than the 60 minute compartments) in these two dive computers. This leads to shorter surface interval times than the DataMaster II and Data Scan 2 models.

4) There is still a limiting factor in these dive computers in the way they function with respect to decompression diving. The manual states: "The DataMaster Sport (Data Scan 3) IS NOT a decompression meter. Although it will aid you in the event you inadvertently exceed the no-decompression limits, Oceanic USA (U.S. Divers) does not advocate this type of diving." The capacity for decompression is limited to 10 minutes total decompression time and, in these models, one stop up to 20 feet. These dive computers will not provide decompression information beyond those limits.

5) If these dive computers are put into a violation mode, they will not function as a dive computer on subsequent dives for 12 hours after the violation. Violations include exceeding 167 feet for any substantial length of time, leaving the "window" (the window is between 10 and 20 feet) of the decompression stop for more than 10 seconds, not decompressing according to the computer's instructions, or exceeding 10 minutes of decompression stop time. The only display functions that are supplied after a violation mode are tank pressure, depth, maximum depth, dive time, surface time, dive number and temperature. The Caution Zone will "freeze" on the display, when in a violation mode, and flash. The information will stay frozen and flash for 12 hours after the dive.

6) High altitude diving with these dive computers is only to 2,000 feet. Above 2,000, these dive computers will not give decompression or air time remaining information. They will function as a tank pressure, depth, maximum depth, bottom time, surface time, dive number and temperature gauge up to 10,000 feet.

7) A failure of this unit (power failure, electronic) would not allow you to dive with a submersible pressure gauge.

Software versions:

DataMaster Sport / Data Scan 3:	Original
DataMaster Sport/S:	New version – on-only switch added

Accessories / Support Material:

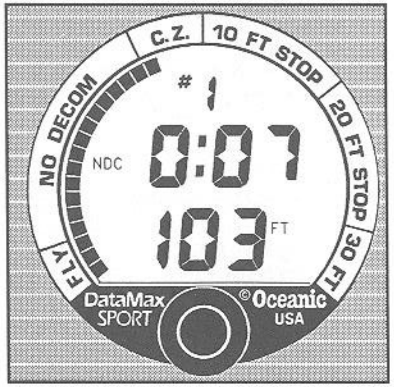
A dive light or a compass is an accessory on the DataMaster Sport
Support material includes manual and simulator

Cost/Warranty:

Console $ 599.95

Warranty: 2 Years with annual maintenance: This warranty specifically does not apply to plastic gauge faces, rubber boots, HP hoses, batteries, damage due to accident or abuse, modification, or tampering. Warranty is non-transferable and applies to original owner only.

Oceanic's **DataMax Sport**



One of the smallest of the dive computers, the DataMax Sport, has lately become very popular in the United States, probably because of its size and simplicity of use. Another Pelagic Pressure Systems innovations, the DataMax Sport was introduced by Oceanic in late 1989. Dr. John Lewis used the same research data from Dr. Powell's study *(see **Other Sport Diving Tables**, chapter 4)* based on a 60 minute compartment off-gassing for this computer. The changes are in the number of compartments used (12) and the half-time range has been increased from 5 to 480 minutes.

The DataMax Sport is turned on by a pre-dive activation button on the face. An excellent dive computer for basic users, easy to understand *(except the ascent warning is not intuitive)*, the DataMax Sport has several additional features over its predecessors. Extra features include an ascent rate indicator, a graphic display of tissue loading, and a time to fly indicator (in earlier models). Violation mode of the DataMax Sport does not shut down computer functions as easily as other Oceanic dive computers. There is up to 5 minutes available on a missed decompression stop before violation.

Oceanic will release another DataMax model (the DataMax Pro, we've heard?) in mid 1991. This model will have a new Time To Fly zone on the graphic Tissue Bar (up-dated to UHMS recommendations for flying after diving) and a new LCD display face.

Construction:

The case back for the DataMax Sport is made of nylon/glass filled Noryl and is covered in a Neoprene boot for extra protection. The display screen is protected with a Lexan polycarbonate resin. This extra covering of Lexan over the display screen helps protect it from damage due to abrasion or abuse, but the face scratches easily.

Power / Activation:

One 3 lithium long life battery powers this dive computer for a manufacturer estimated life of 3 years over varied diving. Shelf life of the battery is expected to be 10 years. Low battery display with give approximately 1 month of use. Battery replacement is through the factory, and a cost estimate can be obtained from an authorized Oceanic dealer.

Activation is by an on/off switch on the gauge face, which runs the computer through a start-up sequence that checks all functions. The start-up screen takes about 15 seconds to establish diagnostics. Power saving deactivation is after 1 hour of non-use on the surface (first dive). Activation depth is 7 feet for starting time and depth calculations.

Features:

- Functional Range to 167' (no-decompression, shortly to 249' in decompression)
- Depth reading capacity to 249'
- Altitude range to 3,000'
- Accuracy + 1%, - 0%
- Calculation every 1 second
- Available in feet or meter depth display

Before Dive Displays:

- Diagnostic check
- Low battery warning
- No decompression scrolling 30'-160'

- Log book (up to 7 dives)

During Dive Displays:

- Current depth
- Total elapsed time
- Dive number
- Ascent rate warning indicator
- No decompression time remaining (digital and graphic)
- Ascent indicator for decompression
- Decompression stop depth (3 stops to 30')
- Decompression stop time
- Out of range - Omitted decompression

After Dive Display:

- Maximum depth
- Total dive time
- Surface Intervals
- Dive number
- New no-decompression limits
- Time to flight — graphic (older models)

Log Book

- Up to 7 dives stored
- Dive number shown
- Dive time
- Maximum depth

Remarks/Limitations

1) The power source must be replace at the factory which means giving up your entire gauge package for a period of time when new batteries come due. Oceanic estimates a 2 to 3 week time period *(starting when they receive them from the dealer)* to change the battery in the computer and return it.

2) A 60 minute off-gas control is used for half-time compartments faster than 60 minutes. This leads to shorter surface interval times than the older DataMaster II and Data Scan 2 models (a blessing). Slower compartments off-gas at the same rate that they on-gas, however we could never make the computer stay saturated more than 24 hours (240 minute half-time compartment), which, in reality, seems to be the controlling slow compartment used.

3) A much better decompression device than all of the Oceanic predecessors, it has the capacity for decompression stops up to 30 feet, with more time available at the stops. The time limit at 30 feet is much shorter than all other decompression models and a stop requirement at that depth can easily put the computer into a violation mode. This is, however fairly excessive decompression diving and is not a recommended practice.

4) If these dive computers are put into a violation mode, they will not function as a dive computer on subsequent dives for 24 hours after the violation. Violations include busting a decompression stop for more than 5 minutes, or exceeding a 30' stop. The only display functions that are supplied after a violation mode are, a time countdown from 12 to 24 hours after the dive will show you when the DataMax Sport will "clear" and be ready for diving, and the tissue Loading Bar graph flashes to alert you that you have omitted a decompression stop.

5) The **Time To Fly** indicator does not indicate enough time to wait before flying. Do Not use or believe this indicator in the older computers. Our recommendation is to wait at least 24 hours for no-decompression dives and 48 hours for decompression dives when using this computer before flying. Newer computers with up-dated Time To Fly indicators will be released in mid 1991 and will have a different color Time To Fly bar and a new style face.

6) Full dive computer functions can be used to 3,000 feet above sea level. Above 3,000, the DataMax Sport will give depth, dive time, surface time, dive number and rate of ascent warning up to 10,000 feet. Above 10,000 the DataMax Sport will not activate.

Software versions:

DataMax Sport: Original
DataMax Pro: New – New Time To Fly graphic display, new LCD face

Accessories / Support Material:

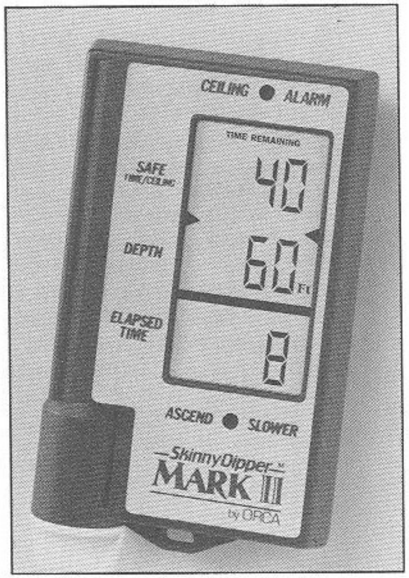
No accessories
Support material includes manual, simulator

Cost/Warranty:

Navcom console	$ 492
Combo console	$ 449.50
Wrist	$ 366
Module	$ 354

Warranty: 2 Years with normal scuba use and annual maintenance: This warranty specifically does not apply to plastic gauge faces, rubber boots, HP hoses, batteries, damage due to accident or abuse, modification, or tampering. Warranty is non-transferable and applies to original owner only.

Orca's **SkinnyDipper Mark II**
Sherwood's **Sigmatech II** *(discontinued)*



Originally marketed by Orca as the SkinnyDipper in 1988, this dive computer became a commercial success with more mass market appeal. The SkinnyDipper was one of the easiest to read and quickest to understand of dive computers. A mere 5.5 ounces and the size of a pack of playing cards, this lightweight computer can be attached, using a slip-on nut, to the high pressure hose without much drag. This unit may also be worn on the wrist in a plastic boot, which is sold separately. Orca soon sold distribution rights to Sherwood, who named their dive computer the Sigmatech.

The beginning of 1989 brought a major recall and name change of both these popular dive computers. The recall was due to a leakage problem in the battery door. A case refitting changed the battery door design, and the SkinnyDipper became the SkinnyDipper Mark II, while the Sigmatech became the Sigmatech II. Sherwood's Sigmatech II, that was distributed for a couple of years (initially as the Sigmatech), was discontinued in mid 1990. The Sigmatech is identical to the SkinnyDipper except it came in a console with an analog SPG, and had a slight variation in the battery door

These Model Based dive computers use the Spencer No-D Limits for calculations. These dive computers are slightly more conservative than the U.S. Navy tables, but not as conservative as the Swiss Models. The SkinnyDipper Mark II (Sigmatech II) have 12 theoretical compartments using half-times ranging from 5 to 480 minutes. This is the algorithm originally developed by Karl Huggins and Craig Barshinger that was used in the Orca Edge. They have a maximum reading capability to 199 feet (at that depth it goes **Out of Range** but calculates at 208 feet), and the ability to calculate at high altitude to 2,000 feet.

Construction:

The SkinnyDipper Mark II (Sigmatech II) case is made of high impact reinforced ABS plastic. The display screen is a made from thin flexible Lexan material. Care should be taken in protecting this type of screen from heavy abrasion *(See Gage-Gard accessories later in this chapter).*

Power / Activation:

Three user replaceable 3 volt lithium batteries power the SkinnyDipper Mark II (Sigmatech II) for a manufacturer estimated life of 500+ hours of continuous use prior to "Lo" Indication. There are about 72 hours (three days) of continuous operation after a "Lo Lo" indication. The batteries can be changed through an external screw-in battery compartment that is sealed by an O-ring. When replacing the batteries, you must turn the computer off, thus losing the memory.

Activation

These computers are turned on by a rotary contact switch located in the battery compartment. The original SkinnyDipper and Sigmatech had leakage problems at these on/off switches, however, no such leakage has been detected from the new models. The start-up screen takes 15 seconds to establish surface reference pressure and this allows you to check all of the functions. Activation depth is 6.1 feet for starting time and depth calculations.

Features:

- Functional Range to 199'
- Depth reading capacity to 199'
- Altitude range to 2,000'
- Accuracy ±1.5'
- Calculation every 3 second
- Available in feet or meter depth display

Before Dive Displays:

- Diagnostic check
- Software version
- Remaining battery power
- Low battery warning
- No decompression scrolling 30'-130'
- Surface power down (Power saving deactivation after 1 hour)

During Dive Displays:

- Current depth
- Total elapsed time
- Decompression stop depth (ceiling)
- Ascent rate indicator
- Ascent indicator for decompression
- Out of range - depth

After Dive Display:

- Maximum depth
- Total dive time
- Surface Intervals
- Time to fly
- New no-decompression limits

Remarks/Limitations

1) One limiting factor of the SkinnyDipper Mark II (Sigmatech II) is the depth range of 199 feet *(though we do not advise going to depths deeper than 130 feet)* for advanced users. These dive computers go Out of Range (OR) if this depth exceeded.

2) The power source is another limitation. Total loss of memory occurs when the battery is changed. It is extremely important that when changing the battery in the SkinnyDipper Mark II there is no current residual nitrogen in memory. If there is, you can not dive this computer after a battery change unless you wait a minimum of 24 hours.

3) In our testing, the batteries never lasted for more than 8 to 12 days of continuous diving, or about 182 to 288 hours of use. This falls far below the manufacturer expected life of the batteries. The positive note is that the computer doesn't have to be sent away for a battery change. Orca should be able to develop a circuitry that has less power drain.

4) There is no time given for decompression stops, making it difficult to determine if there is enough air supply to do the required stop.

5) High altitudes diving with the SkinnyDipper Mark II is only to 2,000 feet *(The Uwatec and Divetronic dive computers make better high altitude device).*

6) Orca's SkinnyDipper Mark II was one of the back-up dive computers during all of our test dives. There were no malfunctions of this unit during testing and the computer always performed without creating additional headaches.

New software versions:

1.0	05-87:	Original SkinnyDipper / Sigmatech
1.0	05-89:	New SkinnyDipper Mark II /Sigmatech II

Accessories / Support Material:

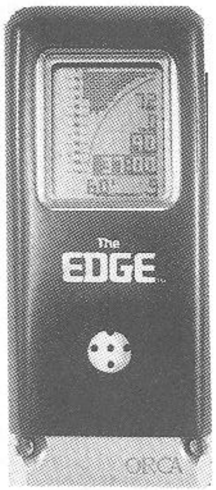
Plasticized holster for mounting to a hose
Support material: Manual, simulator, video

Cost/Warranty:

Wrist/hose mount $ 369

Warranty: 1 Year: This limited warranty shall apply only to the original Buyer of the instrument, and shall not be effective with respect to instruments which have been used in rental, sharing, or similar multi-user arrangements.

Orca's **Edge**



This is the oldest unit of the computers, and at its time of inception, technology dictated size parameters. Weighting in at 1 pound 8 ounces, stories have been told of fending off sharks with the Edge. The machined aluminum case and mineral glass face make the Edge almost "bullet-proof", yet heavy and cumbersome. The Edge can be hose or wrist mounted. A plasticized boot is needed to mount the unit and screw-on hose mounts are provided with the purchase of the gauge.

Manufactured and distributed by Orca, the Edge has been the most used dive computer by diving professionals and was the first successful electronic dive computer in this country. It is also one of the most expensive computers, and is now beginning to give to the pressure of smaller, more sophisticated dive computers. The Edge is a full decompression Model Based dive computer that uses the Spencer No-D Limits for calculations. The Edge has 12 theoretical compartments using half-times ranging from 5 to 480 minutes. This is the algorithm originally developed by Karl Huggins and Craig Barshinger. They have a maximum reading capability to 160' feet (at that depth it goes **Out of Range**), and the ability to calculate at high altitude to 2,000 feet.

The Edge's Bar Graph

The Edge's graphic tissue tracking display is the classic amoung professional divers and is not complicated. There are no numbers associated with this bar graph. The multiple bar graph extends from the top of the screen to a limit line that arcs across the face of the computer. This limit line represents the no-decompression limit for all of the tissue models in the Edge (12 in all). The Edge is the most fascinating of all the computers to watch. The user can actually observe the theoretical in-gassing and out-gassing of their body tissues. The faster tissues are on the left side *(looking at the screen)*, and the slowest tissues are to the right *(the slowest at the far right)*. It becomes apparent how this computer received its name as you watch the tissue bars approach the "edge" of the no-decompression line. On multi-day multiple diving trips the user can see how the slow tissues begin to saturate as diving time increases.

Additional features include a temperature display and a graphic display of all its theoretical compartments in-gassing and out-gassing with a 12 tissue representation *(see sidebar* ***The Edge's Bar Graph****, above).* This decompression unit can graphically and numerically assist in decompression diving.

Construction:

The case is made of machined aluminum and the display screen is a made from mineral glass.

Power / Activation:

One user replaceable 9 volt lithium battery powers the Edge for a manufacturer estimated life of 200+ hours of continuous operation. An Alkaline battery will last about 48 hours. The batteries are changed through an external battery door that is held in place by two screws and sealed by an O-ring. When replacing the battery, you must attach the new battery to the second set of battery clips, and then remove the old battery. This will prevent losing the computer's memory.

Activation Start-up for the Edge is accomplished by flipping the magnetic switch on the back of the computer. That requires pre-dive activation. The start-up screen takes 15 seconds to establish surface reference pressure and this allows you to check all of the functions. Activation depth is 6.6 feet for starting time and depth calculations.

Features:

- Functional Range to 170'
- Depth reading capacity to 175'
- Altitude range to 2,000'
- Accuracy ±1.5'
- Calculation every 3 second
- Available in feet or meter depth display

Before Dive Displays:

- Diagnostic check
- Software version
- Remaining power (DIV 6 version software)
- Low battery warning
- Power saving prompt – manual (DIV 6 version software)
- No decompression scrolling 30'-150'

During Dive Displays:

- Current depth
- Maximum depth (graphic)
- Total elapsed time
- No decompression time remaining (digital & graphic)
- Decompression stop depth (ceiling)
- Decompression stop time (at stop – in pre DIV 6 software)
- Total ascent time (DIV 6 version software)
- Ascent rate indicator
- Ascent indicator for decompression

- Out of range - depth
- Temperature

After Dive Display:
- Maximum depth
- Total dive time
- Surface Intervals
- Time untill flight (DIV 6 version software)
- New no-decompression limits

Remarks / Limitations

1) For a professional full decompression dive computer, the most limiting factor of the Edge is the depth range of 170 feet *(though we do not advise going to depths deeper than 130 feet).* The Edge goes Out of Range (**OR**) if this depth is exceeded. At that depth, the ambient pressure register is storing the largest number that it can. A safety feature for accidental violation of the depth limit for a moment or two has been built in. It defaults to approximately 200 feet of sea water anytime the maximum depth has been exceeded. This safety feature was not designed or tested to allow dives to depths between 165 and 200 feet.

2) The power source is another limitation. The most annoying aspect of the Edge is changing batteries. Changing the battery is difficult and the computer can loses its memory very easily if the procedure isn't followed correctly. This is especially frustrating during a long vacation of multi-day multiple-dives. Also, the low battery indicator gives only eight hours of warning with Lithium batteries, so, a good night's sleep after a day of diving could produce a dead Edge. The new Dive 6 software gives 10 - 18 hours of warning at the "Lo" level on a lithium battery.

3) The entire unit needs to be up-graded. With today's technology, the Edge should be transformed into a light-weight smaller computer with more efficient power consumption. The old DOT Matrix screen makes it difficult to interpret in many positions. The switch is also difficult, at best, to turn on and off because of the difficulty in removing the computer from its plastic boot *(a required procedure on start-up or power-down).* Perceived as the "old standby" by many divers with more experience, this computer is slowly being replaced by lighter weight, easier to read computers with more functions, and better ranges.

4) High altitudes diving with the Edge is only to 2,000 feet *(The Uwatec and Divetronic dive computers make better high altitude devices).*

Software versions:

DIV 1	01-83:	• Original software, original hardware
DIV 2	03-83:	• Modified software for display screen, original hardware
DIV 3	05-83:	• Modified hardware, modified software for new hardware
DIV 4	10-86:	• Added Fahrenheit temperature.
		• shifted #12 (480 min.) slow tissue M-Value from 8.7 to 12.5 feet.,
		• added variable ascent rate indicators of 60/40/20 fpm.
DIV 5	10-86:	• Same as DIV 4 for original hardware
DIV 6	06-90:	• Added total time to surface
		• Added time to fly
		• Increased low battery warning time
		• Added turn off prompt

Accessories / Support Material:

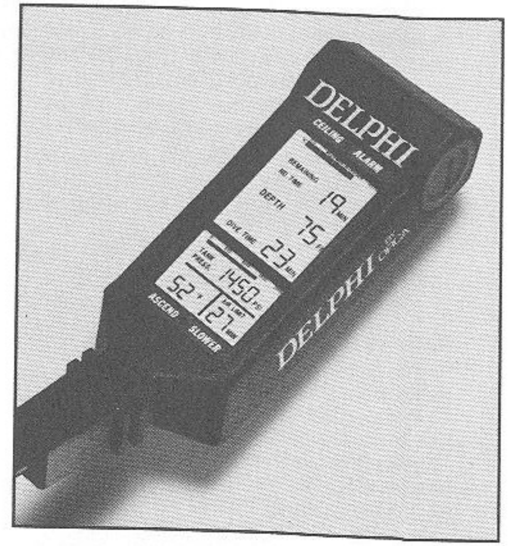
Plasticized holster for hose mounting
Support material: Manual, simulator, video

Cost/Warranty:

Wrist/hose mount $ 720

Warranty: 1 Year: This limited warranty shall apply only to the original Buyer of the instrument, and shall not be effective with respect to instruments which have been used in rental, sharing, or similar multi-user arrangements.

Orca's **Delphi & Delphi Pro**



Designed and manufactured by Orca, the Delphi was introduced in mid 1990 and the Delphi Pro was shipped in late 1990. The Delphi dive computer is a total information package which not only performs time and depth calculations that determine no-decompression and decompression status, it includes air pressure, air consumption, a tissue bar for theoretical compartment saturation status, and temperature. This system is about the same size as any other gauge console combo and is attached to a regulator by a high pressure hose. The Delphi Pro is Orca's advanced Delphi model that has depth functions to 300 feet.

The Delphi's are full decompression Model Based dive computers using the Spencer No-D Limits for calculations. These models are slightly more conservative than the U.S. Navy tables, but not as conservative as the Swiss Models. The Delphi's have 12 theoretical compartments using half-times ranging from 5 to 480 minutes. This is the algorithm originally developed by Karl Huggins and Craig Barshinger that was used in the Orca Edge. The Delphi's have a depth range to 199 feet (300 for the Pro) and a 10,000 feet altitude capability.

Orca's Delphi has an Allowed Nitrogen Tissue Bar, which is not found on the Mare's Mentor. The Allowed Nitrogen Tissue Bar graph shows the status of a tissue in the mathematical Orca Model" *(see sidebar **Allowed Nitrogen Tissue Bar**, page 117).*

Construction:

The Delphi case is made of high impact reinforced Lexan plastic and is covered in a rubberized boot for extra protection. The display screen is protected with a scratch resistant coated Lexan and is recessed in the case about 1/4". This extra covering of Lexan over the display screen helps protect it from damage due to abrasion or abuse.

Power / Activation:

One replaceable 9 volt lithium battery powers the Delphi's for a manufacturer estimated life of 750+ continuous hours (or about 1 month of continuous operation). Alkaline batteries are estimated to last one week. Rechargeable batteries are not recommended for use in the Delphi's because they will give little or no low battery warning before power loss. The batteries can be changed through an external screw-in battery compartment, sealed by an O-ring. When replacing a battery, you have 30 seconds to make the change without endangering the computers memory. After the battery has been properly installed, the Delphi will start-up after 45 seconds showing the current battery voltage *(See sidebar **Reading the battery voltage window**, page 101).*

Activation of the Delphi is by a pressure activated switch, which runs the computer through a start-up sequence that checks all functions. A minimum of 250 p.s.i. cylinder pressure is need to activated the Delphi's switch. The start-up screen takes 45 seconds to establish surface reference pressure and this allows you to check all of the functions. Power saving deactivation occurs either after 30 minutes of wait time before the first dive or when residual nitrogen is not a factor to subsequent dives. Activation depth is 6.1 feet for starting time and depth calculations.

Features:

- Functional Range to 199'
- Depth reading capacity to 199'
- Altitude range to 10,000'
- Log book (last 3 dive, and last 35 hours internally stored in Data Logger)
- Cylinder pressure (up to 5,000 p.s.i.)
- Remaining air time
- Allowed nitrogen tissue bar and tissue number
- Controlling tissue number
- Temperature
- Accuracy ±1.5'
- Calculation every 3 second
- Available in feet or meter depth display

Before Dive Displays:

- Diagnostic check
- Software version
- Remaining power
- Low battery warning
- No decompression scrolling 30'-130'
- Surface power down (Power saving deactivation)
- Log book mode

During Dive Displays:

- Current depth
- Total elapsed time
- No decompression time remaining (digital)
- Decompression stop depth (ceiling)
- Total ascent time
- Ascent rate indicator
- Ascent indicator for decompression
- Out of range - depth
- Cylinder pressure
- Remaining air time
- Temperature

After Dive Display:

- Maximum depth
- Total dive time
- Surface Intervals
- Waiting time prior to flight
- New no-decompression limits
- Allowed nitrogen tissue bar and tissue number
- Cylinder pressure
- Temperature

Log Book:

- 3 dives stored
- Dive time
- Dive number
- Surface Intervals
- Maximum depth
- Dive profiles (up to 35 hours at 2.5 minute increments – factory)

Remarks / Limitations

1) One limiting factor *(at least for a small number of professional divers)* of the Delphi is the depth range of 199 feet *(though we do not advise going to depths deeper than 130 feet)* for advanced users *(See Mares Mentor)*. The Delphi Pro will function to 300 feet.

2) The power source is another limitation. The recommended power source for the Delphi is a Kodak Ultralife 9 volt Lithium cell battery. Kodak quit manufacturing this battery for a period of time in 1990, but they have now decided to continue its manufacture. Orca estimates battery life to be 750+ continuous hours before reaching the "Lo" indication. At that time, the Delphi will function another 75 hours before reaching the "Lo Lo" indication, leaving 15 hours before the battery must be changed. We found in our testing that the battery failed within 40 hours of reaching a "Lo" indication and within only 2 to 4 hours of reaching a "Lo Lo" indication. The apparent problem is with the Lithium battery which appears to have a much faster voltage drop-off rate than expected by the manufacturer. We also found that cold weather top side made the battery drop significant voltage. Our recommendation is to change the battery soon (within 10 hours) of reaching a "Lo" battery indication.

Allowed Nitrogen Tissue Bar

An advanced feature of the Orca Delphi and Delphi Pro is the Allowed Nitrogen Tissue Bar and Tissue Number. The Allowed Nitrogen Tissue Bar is a graph that shows the status of a tissue compartment in the mathematical Orca Model. The number to the left of the bar shows which compartment is being displayed. The Orca Model has 12 compartments and each are displayed sequentially on the surface. Underwater, only the controlling compartment *(the compartment that is calculated to reach 100% first)* is displayed by the Allowed Nitrogen Bar. If a compartment reaches 100%, the computer goes into decompression because it has reached its Theoretical Nitrogen Over-Pressure Limit and the model does not allow the diver to surface without decompression. The Tissue Bar also scrolls on a safety stop that is less than 12 feet.

The controlling compartment numbers (1-12) are displayed immediately to the left of the bar. The fastest compartment is number 1, with a 5 minute half-time. The slowest compartment is number 12, with a 480 minute half-time. The compartment numbers can be used as a guide to estimate the length of no-decompression limits or required decompression. In General, the larger the number, the slower the controlling compartment, the longer the no-decompression limit, and the longer the required decompression time if the no-decompression limit is exceeded.

3) You must remember to turn on the Delphi at the surface and the computer has to perform its pre-dive start-up before diving it. For those in the habit of turning their air on at the water's surface, this dive computer must be held in the air for about 45 seconds.

4) The Air Limit, which is read in minutes, zeros out at 500 p.s.i. This is often annoying because divemasters tend to freak-out when they see *(or think they see)* you're out of air. Orca purposely designed this characteristic into the Delphi as an additional safety feature *(just let the divemaster know ahead of time)*.

5) High altitudes diving with the Delphi is to 10,000 feet. Above 2,000, to 10,000 feet you must wait for equalization to the ambient pressure at the new altitude or the Delphi can give false decompression readings. There is a special initialization process if you don't have time to acclimate at altitude. First, turn on the Delphi at your initial altitude, then just before entering the high altitude lake, reset the Delphi's surface reference by removing the tank air pressure (turning off the tank and bleeding the regulator) for 5 minutes. The Delphi will now make proper calculations for the new altitude.

6) As of this writing, the Data Logger (dive profile recall) is only accessible by sending the Delphi back to the manufacturer for data output. Orca will have a data reader for the consumer market in early 1991.

7) A failure of this unit (power failure, electronic) would not allow you to dive with a submersible pressure gauge.

8) There is a recall on software version 3.0 in serial numbers ranging from 6500 to 8785 (and some lower numbers). To verify the 3.0 version number, simply turn the computer on and wait for the second display screen to appear. The depth display area in the center will show the software version. **Version 3.0 should not be used for decompression diving.**

9) A home use PC hardware/software system is needed to unload DataLogger data. The technology exists for Orca to make publicly available the components for down-loading the Delphi's (Mares Mentor's) memory. This system could even be implemented as a PC dive computer electronic log book like SeaQuest currently has with their SME-ML R-1 and Solution.

New software versions:

1.0	10-89:	Original
3.0	06-90:	Improved Low Battery Detection
4.0	12-90:	Improved decompression software, phosphorescent screen display, and modified battery door to hold the battery from moving.

Accessories / Support Material:

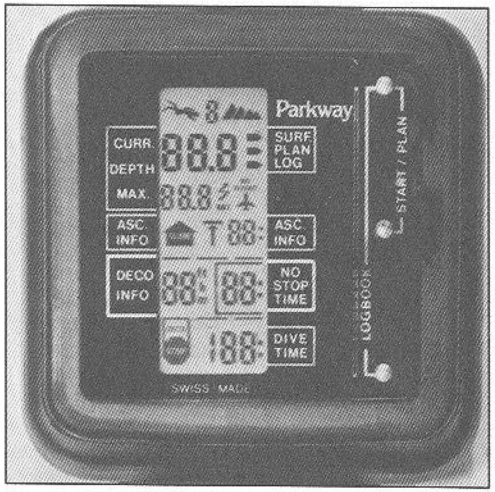
Slate, knife, and padded slip-on protector pouch
Support material: Manual, simulator, video

Cost/Warranty:

Console $ 670

Warranty: 2 Years: This limited warranty shall apply only to the original Buyer of the instrument, and shall not be effective with respect to instruments which have been used in rental, sharing, or similar multi-user arrangements.

Parkway's **Legend**



Parkway introduced their new dive computer, the Legend, in 1990. This sophisticated dive computer is similar to the Aladin Pro and is manufactured by Uwatec of Switzerland. Designed with advanced divers in mind, the Legend has all the additional features that the Aladin Pro has incorporated in its new model, including waiting time prior to flying, total ascent time, decompression stop time, and an acoustic alarm for ascent rate or decompression violations. This multi-level Swiss Model dive computer uses the newest version of Buhlmann's ZHL-16 tables. There is less time at depth because of the more conservative approach of these tables *(see Aladin)*. The Legend uses 6 compartments with half-time ranges from 6 to 320 minutes. The Legend is a bit larger than its cousins the Aladins, but remains a small convenient size, and it easy to read and understand.

The Legend, like the Aladins and Monitors, is part of the group of the best high altitude dive computers on the market. The Legend can be used to altitudes of 13,200 feet as either a desaturated dive computer *(after waiting the appropriate time)* or as a repetitive dive computer at altitude which calculates at a higher saturation level. The Legend is an advanced dive computer with full decompression and high altitude functions.

Construction:

Made of Lexan Polycarbonate casing, this is a sealed dive computer. The screen is protected from a thin outer layer of Lexan that helps prevent abrasion, however, this is not a rigid outer covering *(see Gage-Gard accessories for screen protectors)*.

Power / Activation:

Power specifications is identical as in the Aladin models, using one 3.6 volt lithium battery. The battery is potted in the case and must be changed through the factory. Based on a typical dive duration of 45 minutes and desaturation of 10 hours, manufacturer estimated life of the battery is 6-7 years at 50 dives a year, 5 years at 100 dives a year, 2-3 years at 200 dives a year, and 1-2 years at 500 dives per year.

Activation of the Legend is immediate with an immersion type switch. The Legend is a "Live" dive computer constantly monitoring atmospheric pressure changes like the Aladin Sport. Activation depth is 4 feet for calculations.

Features:

- Depth range to 330'
- Altitude range to 13,200'
- Log book
- Dive plan mode - not a simulator
- Accuracy ±1' ffw
- Calculation every 1 second
- Auto activation (immersion switch)

Before Dive Displays:

- Diagnostic check
- Low battery indicator
- No decompression scrolling 30'-140'
- Surface power down (Power saving deactivation)
- Log book mode
- No flying indicator
- Waiting time prior to flying
- High altitude adaptation time
- High altitude sector

During Dive Displays:

- Current depth
- Maximum depth
- Total elapsed time
- No decompression time remaining
- Decompression stop depth
- Total ascent time
- Decompression stop time
- Ascent rate indicator
- Acoustic ascent rate alarm
- Ascent indicator for decompression
- Acoustic ascent alarm for decompression
- Out of range - depth, omitted decompression

After Dive Display:

- Maximum depth
- Total dive time
- Surface interval time
- Desaturation time
- No flying icon
- Waiting time prior to flight
- New no-decompression limits (in Dive plan mode)
- High Altitude sector
- Low battery indicator
- Decompression omitted
- Tissue type affected in decompression

Log Book:

- 9 dives
- Dive number shown
- Dive time
- Maximum depth

- Surface intervals
- High Altitude sector
- Ascent rate violation
- Decompression omitted

Remarks / Limitations

1) Parkway's only dive computer, the Legend is one of the most sophisticated dive computers on the market, and is a very good choice for advanced divers.
2) Waiting time prior to flight is hours shorter than Spencer No-D Limits Models. This model calculates to 8,000 feet for flying after a dive. We recommend following UHMS procedures outlined in Chapter 10.
3) A excellent dive computer for high altitude, decompression, or repetitive diving.

Software versions:

ZHL-16 Updated.

Accessories / Support Material:

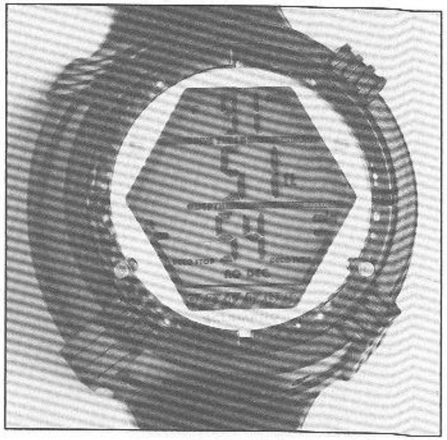
None at this time

Cost/Warranty:

Wrist	$ 590
Console 1	$ 740

Warranty: 12 months: Servicing or tampering by anyone other than the Parkway Fabricators, Inc. will void the warranty. This also applies to battery replacement. The Legend computer should not be subjected to any "Dry" pressure testing. Any testing must be carried out with the unit submerged in water.

Scubapro's **DC-11**



Distributed by Scubapro in Europe since mid 1990, the DC-11, is probably, at this time, one of the most sophisticated full decompression computers available with 45 different functions. This is a very small dive computer, with the screen size about the size of the DataMax Sport. Made by Divetronic AG, it is a multifunctional dive computer using the newest Buhlmann-Hahn (P-5) Swiss Model for calculations. This makes the DC-11 significantly more conservative than the U.S. Navy Tables and, also more conservative than the Uwatec models and the Micro Brains. The P-5 is an updated version of the Swiss Model which has been given additional individual saturation allowances that account for bounce diving, rapid ascents, multiple ascents in one day, and repeated dives. The DC-11 has 6 theoretical compartments using half-times ranging from 6 to 600 minutes.

The DC-11's algorithm is compensated in the same manner as the Micro Brains for high altitude dives except its range is to 11,500 feet. The display is programmable by the user for meters and C° or feet and F°. The DC-11 also can freely program safety factors into the model (by selecting high altitude ranges at lower elevations).

The DC-11 will handle full decompression diving. Large numbers indicate the depth of the first decompression stop, decompression time and ascent time. Other special features include a fast time dive planner *(12 times faster)*, Logbook Memory, a Dive Recorder and phosphorescent display lighting.

Construction:

The DC-11 case is made from glass reinforced polyamide plastic which is hermetically sealed in silicone gel. This case holds the entire contents of this 5.4 ounce dive computer. The screen is six-sided, is 1 3/4" across, and is covered by a thin film of Lexan lending itself to abrasion or abuse *(See Gage-Gard accessories)*.

Power / Activation:

Two rechargeable 3 volt lithium batteries **power** the DC-11 for a manufacturer estimated use life of 10,000 hours or 10-12 years based on unrestricted diving. The batteries can be recharged by an external charger (LM-11) that is sold to dive stores. Batteries are recommended to be charged if the DC-11 is used at least 200 diving hours per year, and if not used accordingly, charging is not recommended. One hour charging is good for 10 hours of diving. The batteries must be factory replaced.

Activation of the DC-11 is by an immersion switch, which turns the computer on after a start-up. The start-up screen takes about 5 seconds and must be allowed to run or the DC-11 will read incorrectly underwater. Power saving deactivation occurs after about 4 minutes of non-use and the DC-11 must be re-started before directly descending on a dive. A magnetic reed switch is built into the case for deactivation or manual clearing with an external magnet *(one is provided with the computer)*. Activation depth is 5 feet for calculations.

Features:

- Functional Range to 300'
- Depth reading capacity to 300'
- Altitude range to 11,500'
- Log book (last 6 dive until desaturation, then last 3 dives)
- Dive Recorder (total number of dives, total hours, maximum depth ever)
- Dive Planner (to 262', up to 199 min., ascent times up to 99 min., deco stops to 70')
- Accuracy ±1/3'
- Phosphorescent display lighting
- Calculation every 1 second (or 5 seconds for decompression)
- Display depth programmable in feet or meter

Before Dive Displays:

- Diagnostic check
- Software version
- No decompression scrolling 41'-149'
- Surface power down (Power saving deactivation)
- Programmable altitude zone
- Log book mode
- Dive planner (12 times faster than real time)
- Temperature

During Dive Displays:

- Current depth
- Maximum depth
- Total elapsed time
- No decompression time remaining (graphic and digital)
- Decompression stop depth (up to 70 feet)

- Decompression stop time
- Total ascent time
- Ascent rate indicator
- Ascent indicator for decompression
- Out of range - omitted decompression, more than 99 min. total ascent time, deeper than 70' stop
- Temperature

After Dive Display:
- Maximum depth
- Total dive time
- Surface Intervals (in log book only)
- Do not fly indicator
- Waiting time to fly
- New no-decompression limits
- Desaturation time
- Dive simulator (12 times faster than real time)

Log Book:
- 3 dives stored (last 6 dives until desaturation, then last 3 dives)
- Dive time
- Dive counter
- Surface Intervals
- Maximum depth
- Dive Recorder (total number of dives, total hours, maximum depth ever)

Remarks/Limitations
1) Found only in Europe at this writing, though, Scubapro USA may decide to import the DC-11.
2) Activation of the DC-11 must be performed properly or it will not read correctly underwater. The start-up process takes about 5 seconds. It also deactivates after about 4 minutes and must be re-started before using underwater in a dive mode.
2) A horizontal bar is used to graphically display no-decompression status. We found this bar to be very small and harder to distinguish than the triangle found on the Micro Brains.
3) The **"Ascend"** warning indicator makes more sense than the one used in the Micro Brains because it indicates **"Slow"** which is more appropriate and clearly understood by the user.
4). The manual is not as well organized as many other dive computers and it does not contain all of the DC-11's specifications.

Software versions:
P-5

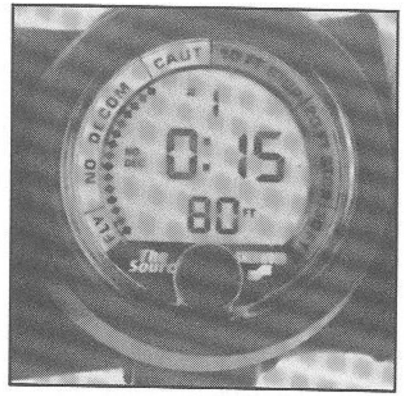
Accessories / Support Material:
none at this time

Cost/Warranty:
Wrist	$ Only found in Europe at this time (250 British pounds)
Slip-on	$ Only found in Europe at this time
Console	$ Only found in Europe at this time

Warranty: 1 Year: This guarantee does not cover fragile parts (crystals and reed switches) and components subject to wear, such as batteries, boots, or straps. No guarantee claims can arise from damage caused by chemical and electrochemical action, and from abnormal environmental conditions. This guarantee ceases to be valid if repairs or manipulations are performed by people not authorized by Scubapro.

Sherwood's **Sigmatech** (Discontinued see Orca SkinnyDipper Mark II)

Sherwood's **Source**



One of the smallest of the dive computers, and the same computer as Oceanic's DataMax Sport *(See DataMax Sport overview)*, the Source is another popular dive computer. The difference in this model over the Oceanic DataMax is the Time To Fly indicator on the bar graph is missing.

The Source is turned on by a pre-dive activation button on the face. An excellent dive computer for basic users, easy to understand *(except the ascent warning is not intuitive)*, the Source has several additional features over its predecessors. Extra features include an ascent rate indicator, and a graphic display of tissue loading.

Sherwood will release another Source model in mid 1991. This model will have a new Time To Fly zone on the graphic Tissue Bar, it will allow full computer operation up to 10,000 feet, and have a more flexible violation mode minimizing the chance of computer shut down. To identify the newer model, a silver on/off button is replacing the black one.

Construction:
The case back for the Source is made of nylon/glass filled Noryl and is covered in a Neoprene boot for extra protection. The display screen is protected with a Lexan polycarbonate resin. This extra covering of Lexan over the display screen helps protect it from damage due to abrasion or abuse, but the face scratches easily *(See Gage Gard accessories)*.

Power / Activation:
One 3 lithium long life battery **powers** this dive computer for a manufacturer estimated life of 3 years over varied diving. Shelf life of the battery is expected to be 10 years. Low battery display with give approximately 1 month of use. Battery replacement is through the factory, and a cost estimate can be obtained from an authorized Sherwood dealer.

Activation is by an on/off switch on the gauge face, which runs the computer through a start-up sequence that checks all functions. The start-up screen takes about 15 seconds to establish diagnostics. Power saving deactivation is after 1 hour of non-use on the surface (first dive). Activation depth is 7 feet for starting time and depth calculations.

Features:
- Functional Range to 167'
- Depth reading capacity to 249'
- Altitude range to 3,000'
- Accuracy ±1%
- Calculation every 1 second
- Available in feet and meter depth display

Before Dive Displays:
- Diagnostic check
- Low battery warning
- No decompression scrolling 30'-160'
- Log book (up to 7 dives)

During Dive Displays:

- Current depth
- Total elapsed time
- Dive number
- Ascent rate warning indicator
- No decompression time remaining (digital and graphic)
- Ascent indicator for decompression
- Decompression stop depth (3 stops to 30')
- Decompression stop time
- Out of range - Omitted decompression

After Dive Display:

- Maximum depth
- Total dive time
- Surface Intervals
- Dive number
- New no-decompression limits
- Time to flight – graphic (in newer models)

Log Book

- Up to 7 dives stored
- Dive number shown
- Dive time
- Maximum depth

Remarks / Limitations

1) The power source must be replace at the factory which means giving up your entire gauge package for a period of time when new batteries come due. Sherwood estimates a 2 to 3 week time period *(starting when they receive unit from the dealer)* to change the battery in the computer and return it.

2) A 60 minute control is used for half-time compartments faster than 60 minutes. Slower compartments off-gas at the same rate that they on-gas, however like the DataMax Sport, we could not ever make the computer stay saturated more than 24 hours (240 minute half-time compartment). See Oceanic DataMax Sport for more information.

3) The capacity for decompression is for stops up to 30 feet, with more time available at the stops. The time limit at 30 feet is much shorter than other decompression models and a stop requirement at that depth can easily put the computer into a violation mode. This is, however, fairly excessive decompression diving and is not a recommended practice.

4) If this dive computers are put into a violation mode, they will not function as a dive computer on subsequent dives for 24 hours after the violation. Violations include busting a decompression stop for more than 5 minutes, or exceeding a 30' stop. The only display functions that are supplied after a violation mode are, a time countdown from 12 to 24 hours after the dive will show you when the Source will "clear" and be ready for diving, and the tissue Loading Bar graph flashes to alert you that you have omitted a decompression stop.

5) Full dive computer functions can be used to 3,000 feet above sea level. Above 3,000, the Source will give depth, maximum depth, bottom time, surface time, dive number and rate of ascent warning up to 10,000 feet. Above 10,000 the Source will not activate. The new model will operate to 10,000 feet in all functions.

Software versions:

Source: Original

Source: Silver button
- New display screen
- Modified software to minimize shut down
- Altitude compensated to 10,000 feet
- Time to Fly feature added graphic display, new LCD face

Accessories / Support Material:

No accessories

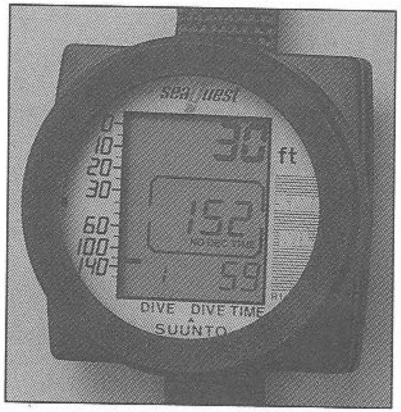
Support material includes manual, simulator, and video in 1991

Cost/Warranty:

Combo console	$ 473
Wrist	$ 368
Module	$ 356

Warranty: 2 Years with normal scuba use and annual maintenance: This warranty specifically does not apply to plastic gauge faces, rubber boots, HP hoses, batteries, damage due to accident or abuse, modification, or tampering. Warranty is non-transferable and applies to original owner only.

Suunto's **SME-ML** & **SME-ML R1**



Suunto developed the first small wrist mounted dive computer that was introduced to the United States by SeaQuest in 1987 as the SME. There were actually two versions in the beginning, consisting of the USN and the ML models. The USN was Table Based while the ML was a multi-level Model Based dive computer. The SME-ML became very successful partly because of its lightweight construction and small size (2.5 inches square), but mainly because of its sophisticated list of multi-level no-decompression and decompression features. The SME-ML is also a full decompression computer, with a maximum functional depth to 200 feet.

The Suunto ML's M-values are based on the Spencer No-D Limits using a Nikkola algorithm. This algorithm is very similar to the Huggins-Barshinger used in Orca models, with the exceptions of extending the half-time range to 2.5 to 480, and using 9 compartments.

The SME-ML is the only computer equipped with a user initiated dive profile recall *(at this time)*, which can recall up to 10 hours of dive memory. This scrolling memory recall shows the maximum depth attained in three-minute intervals and corresponding time and depth of each of the previous dives (up to 10 hours). The total underwater time and the maximum depth will be shown using the recall. The SME-ML's drawback is mastering the use of the recall function.

In 1989, Suunto released an up-dated software called the SME-ML R-1. The R-1 software has taken the place of the SME-ML, which has been discontinued. The R1 added several new features including an easier to use recall function and a numeric maximum depth displayed. The R-1 software version is indicated by a small "R-1" screened onto the face of the dive computer.

Construction:

The SME-ML's are made of a lightweight polymer plastic and are available in four different configurations. The display screen is protected with an outer protective scratch resistant coated high impact plastic covering. This extra outer protective covering over the display screen helps protect it from damage due to abrasion or abuse.

Power / Activation:

Two factory *(retailer)* replaceable 1.5 volt Silver Oxide batteries power the SME-ML's for a manufacturer estimated life of 1,500 hours, equivalent to about 100 starts. The batteries must be changed by the retailer which is less convenient for extended dive vacations, but the battery life is much longer than user replaceable models.

Activation of the SME-ML's is by immersion into water *(an immersion switch)*, and raising it above the surface for at least 5 seconds which runs the computer through a start-up sequence. Activation depth is 5 feet for starting time and depth calculations. The SME-ML's are deactivated within one hour if you do not dive after initial activation. After diving, the SME-ML's deactivate when the last series of dives has no effect on repetitive dives.

Features:

- Functional Range to 200'
- Depth reading capacity to 230'
- Altitude range to 1,600'
- Logbook (last 10 dive hours, profiled in 3 min. increments)
- Software version
- Accuracy ±3.45'
- Calculation every 1 second (3 seconds for slow compartments)
- Available in feet or meter depth display

Before Dive Displays:

- Diagnostic check
- Low battery warning
- No decompression scrolling 30'-190'
- Surface power down (Power saving deactivation after 1 hour)
- Logbook mode (dive profile)

During Dive Displays:

- Current depth
- Maximum depth (graphic)
- Total elapsed time
- No decompression time remaining (digital)
- Decompression stop depth (graphic ceiling, to 90')
- Stop time
- Ascent rate indicator
- Ascent indicator for decompression
- Out of range - depth, excessive decompression time (more than 30 min.)

After Dive Display:

- Maximum depth (bar graph; plus digital on R-1 version)
- Total dive time
- Surface Intervals
- Do not fly icon
- New no-decompression limits

Log Book:

- 10 hours of dives stored
- Dive time
- Dive number
- Surface Intervals
- Maximum depth (graphic; digital on R-1 version)
- Dive profiles (up to 10 hours at 3 minute increments)

Remarks / Limitations

1) One limiting factor of the SME-ML's is the depth range of 200 feet *(though we do not advise going to depths deeper than 130 feet)* for advanced users. The computer goes into a Error mode (Err) and locks-up displaying only time and depth. It will not provide any data about decompression information until a surface interval that allows total off gassing of residual nitrogen has elapsed.

2) The power source must be replaced at the factory or by a retailer which means giving up your computer for a period of time when new batteries come due. The battery change can be accomplished by some dealers rather quickly, so check options before you just leave it.

3) You must remember to dip the SME-ML's at the surface so that the computer performs its pre-dive start-up before diving it. After activation, this dive computer must be held in the air for at least 5 seconds before descending .

4) High altitudes diving with the SME-ML's is to only 1,600 feet. It needs to be switched on at the dive site for the computer to indicate true depth.

5) The dive recall was a source of frustration in the earlier SME-ML model (*this has been rectified in the R1 model)*. The frustration mounted from numbed fingers that failed to press the contacts for the precise 3 seconds required in these older models.

6) The depth of the ceiling is not as easy to read underwater as other models because it is given graphically instead of numerically.

7) There is an extensive array of support materials and accessories for these models.

Software versions:

ML	1987	Original SME-ML
R1	1989	SME-ML R1 with improved dive profile recall

Accessories / Support Material:

The computer comes with a Dive Plan/Back-Up Data slate with a profile dive log on the backside *(that logs four dives)* and a protective pouch.

Support material includes a Multi-Level Log Book *(for 75 dives)* $12.95, a Desktop Log and Simulator for the P.C. $45, and a training video $20, a manual, workbook, Instructor's Guide, simulator, and video

Cost/Warranty:

Capsule only	$ 490
Wrist unit	$ 520
Hose mount	$ 500
2 gauge console	$ 590
3 gauge console	$ 630

Warranty: 2 Years: This limited warranty does not cover damage to the produce resulting from improper usage, improper maintenance, neglect of care, alteration or unauthorized repair. The SME-ML must be inspected annually and serviced as necessary by a Suunto Dealer or a qualified repair facility to keep this warranty valid.

Suunto's **Solution**

One of the newest developments in dive computers in 1990 was Suunto's Solution. Distributed by SeaQuest in early 1991, this small dive computer has all you could ask for in features. If the success of the SME-ML's is any indication of what the Solution will do, then divers take note. New features include an expanded depth range to 325 feet, altitude range to 8,200 feet, expanded decompression capabilities, variable ascent rate display, audible alarms (for excessive ascent rate, omitted decompression, excessive depth, and excessive decompression), and an expanded memory that allows log book, dive history and dive profiles, plus a 4 time speed simulator.

It is of lighter weight construction than the ML's and the same small size (2.5 inches), but has a larger display screen. The Solution, unlike the SME-ML, is a full decompression dive computer. The Solution's algorithm is the same as the SME-ML's *(see SME-ML in overview)*.

Construction:

The Solution is made of a lightweight polymer plastic and is available in four different configurations. The display screen is protected with an outer protective scratch resistant coated high impact plastic covering. This extra outer protective covering over the display screen helps protect it from damage due to abrasion or abuse.

Power / Activation:

One factory *(retailer)* replaceable 3.7 volt Lithium battery **powers** the Solution for a manufacturer estimated life of 2000 hours. The batteries must be changed by the retailer which is less convenient for extended dive vacations, but the battery life is much longer than user replaceable models.

The Solution is always ready for use and will **activate** if submerged. It is not necessary to turn it on before diving. Activation depth is 5 feet for starting time and depth calculations. The Solution's display is deactivated within 3 minutes if you do not dive after initial activation.

Features:

- Functional Range to 325'
- Depth reading capacity to 325'
- Altitude range to 8,200'
- Log Book Memory (last 8 dive hours, without profile)
- Dive Profile Memory (last 8 dive hours, with profile)
- Dive History Memory (Total dive time hrs., total dives, maximum depth)
- 4X speed dive simulator
- Direct PC interface program
- Software version
- Temperature
- Accuracy ±1%
- Calculation every 1 second (3 seconds for slow compartments)
- Available in feet or meter depth display

Before Dive Displays:

- Diagnostic check
- Low battery indicator
- No decompression scrolling 30'-150'
- Surface power down (Power saving deactivation after 3 minutes)
- Log book modes (dive profile, dive memory, dive history)
- Dive simulator

During Dive Displays:

- Current depth
- Maximum depth (graphic)
- Total elapsed time
- No decompression time remaining (digital)
- Decompression stop depth (graphic ceiling, to 140')
- Total ascent time
- Ascent speed indicator
- Ascent rate alarm (visual and acoustic)
- Ascent alarm for decompression (visual and acoustic)
- Omitted decompression alarm (visual and acoustic)
- Out of range (Er) - omitted decompression, maximum depth exceeded

After Dive Display:

- Maximum depth (bar graph, digital)

- Total dive time
- Surface Intervals
- Do not fly icon
- Time to fly
- New no-decompression limits
- All log book functions

Log Books:

- 8 hours of dives stored
- Dive time
- Dive number
- Surface Intervals
- Maximum depth (graphic and digital)
- Total dive time in hours
- Total number of dives
- Exceeded warnings (ascent rate, decompression dive, ceiling violated)
- Dive profiles (up to 8 hours at 3 minute increments)

Remarks/Limitations

1) The manual is not up to the standard of such a fine instrument. It is poorly compiled, lay-out is unfriendly, and instructions are not complete or concise.

2) The power source is estimated to last 2,000 hours. The manual, however, states "The Solution should be serviced every two years, or 200 dives (whichever comes first). During servicing, the operation of the unit will be checked and it's battery replaced."

3) The power source must be replaced at the factory or by a retailer which means giving up your computer for a period of time when new batteries come due. The battery change can be accomplished by some dealers rather quickly, so check options before you just leave it.

4) There is an extensive array of support materials and accessories for these models.

Software versions:

1990 Original Solution

Accessories / Support Material:

The computer comes with a Dive Plan/Back-Up Data slate with a profile dive log on the backside *(that logs four dives)* and a protective pouch.

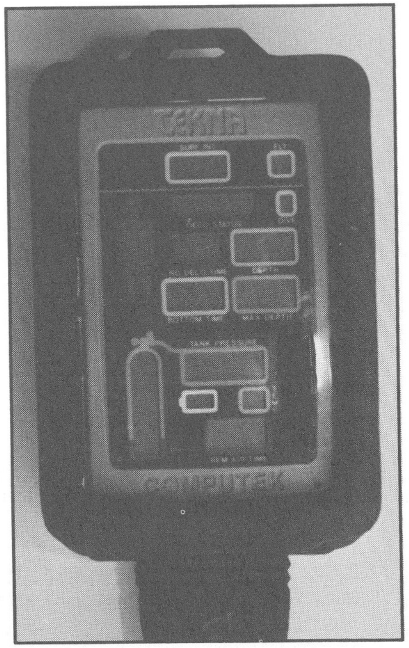
Support material includes a Multi-Level Log Book *(for 75 dives)* $12.95, a Desktop Log and Simulator for the P.C. $45, and a training video $20, a manual, workbook, Instructor's Guide, and video

Cost/Warranty:

Capsule	$ 610
Wrist unit	$ 620
Hose mount	$ 660
2 gauge console	$ 700
3 gauge console	$ 740

Warranty: 1 Year: This limited warranty does not cover damage to the product resulting from improper usage, improper maintenance, neglect of care, alteration or unauthorized repair. This warranty will automatically become void if proper preventive maintenance procedures have not been followed (must be inspected annually and serviced as necessary by a Suunto Dealer or a qualified repair facility to keep this warranty valid).

Tekna's **Computek**



Manufactured and distributed by Tekna since mid 1990, the Computek has to be one of the easiest to read full decompression dive computers available. This is also the largest dive computer on the market, with the screen size of 2 1/4" wide by 3 1/2" high. The Computek uses a Hahn-Tekna algorithm and it falls in the Swiss Model category for calculations. This new model makes the Computek more conservative than all other dive computers except possibly the P-5 Model from Scubapro Europe. This is an updated version of the Swiss Model which has been given additional individual saturation allowances. The Computek has 8 theoretical compartments using half-times ranging from 8 to 689 minutes. Note that this is the longest half-time used in any dive computer to date.

The Computek is a complete dive computer instrument console, including cylinder pressure, air time remaining, and temperature. The Computek is the first dive computer to use fill-up "pictographs" *(graphic icons representing a person and a dive cylinder)* along with numeric displays to help simplify display information. The display screen also has colored frames that separate information into important groups such as **Red** for decompression information *(and the diver pictograph)*, **Green** for tank information *(and the tank pictograph)*, **Orange** for vital signals like low on air and remaining air time, **Blue** for depth, maximum depth, and temperature, and **Yellow** for surface interval, fly status, dive number and bottom time.

The Computek will handle full decompression diving up to a 45 minute total ascent time. Other features include a dive log and dive planning, and a light sensor that controls an automatically activated backlight.

Construction:

The Computek case is made from glass reinforced polyamide plastic which is O-ring sealed to the face. The face is made from a high impact Lexan. The screen is recessed within the case and face keeping it away from typical abrasion or abuse.

Power / Activation:

One replaceable 3 volt lithium battery will **power** the Computek for a manufacturer estimated use life of 1,500 hours. The batteries can be changed by the user through an external battery screw cap. Batteries are recommended to be changed when the battery display starts flashing, which is at 25% of capacity (or one segment showing in the battery display pictograph). **Warning**: Memory loss will occur when the battery is removed. If you remove the battery before the time to fly reaches 0 hours (or when the display is blank), you will cause Computek to lose track of your current residual nitrogen level. In this situation you must wait 24 hours before initiating any dives.

Activation of the Computek is by an air pressure activated switch, which is fully automatic. The start-up screen takes about 5 seconds. Activation depth is 7 feet for calculations.

Features:

- Functional Range to 160' (decompression to 220')
- Depth reading capacity to 220'
- Altitude range to 10,000'
- Log book (up to 10 dives until desaturation)
- Accuracy ±1'
- Automatically activated backlight
- Calculation every 1 second (decompression calculations every 6 seconds)

Before Dive Displays:

- Diagnostic check
- No decompression scrolling 30'-130'
- Dive number
- Tank pressure (digital and graphic)
- Remaining air time
- Remaining battery power
- Temperature

During Dive Displays:

- Current depth
- Maximum depth
- Total elapsed time
- No decompression time remaining (graphic & numeric)
- Decompression stop depth
- Total ascent time
- Ascent rate indicator
- Ascent indicator for decompression
- Out of range - omitted decompression, depth, over 45 min. ascent time
- Cylinder pressure (digital and graphic)
- Remaining air time
- Remaining battery power
- Backlight (if low ambient light detected)
- Temperature

After Dive Display:

- Maximum depth
- Total dive time
- Surface Intervals
- Do not fly indicator
- New no-decompression limits
- Cylinder pressure Digital and graphic)
- Remaining air time
- Remaining battery power
- Light sensor (to turn log book on)
- Temperature

Log Book:

- Up to 10 dives stored (until desaturation)
- Dive time
- Dive counter
- Surface Intervals
- Maximum depth

Remarks / Limitations

1) Total loss of memory occurs when the battery is changed. It is extremely important that when changing the battery in the Computek there is no current residual nitrogen in memory. If there is, you can not dive this computer after a battery change unless you wait a minimum of 24 hours.

2) The Dive log function can be only activated before the Fly indicator has appeared. As soon as the Fly icon appears, the log function and display information is lost. This can occur whenever the Computek has out-gassed enough to allow flying, and without warning, cancel the log book function and display information. If you hadn't written down the previous dives from the log, then it will be too late to do so.

3) There are three default conditions that shut down the Computek. The first default is diving deeper than 220 feet. If you continue at this depth for less than 1 minute, a warning of impending default will occur. The default will clear if you ascend (within 1 minute). If you continue at this depth for greater than 1 minute, the default will become permanent. You must then rely on standard tables to determine your decompression status. The second default is ascending above an indicated stop depth before waiting the required period. Computek will allow a cumulative total of 2 minutes above your actual ceilings during any repetitive dive sequence before a permanent default occurs. The third default is an accumulative total ascent time requirement of 45 minutes or more. In this event, Computek will permanently enter default mode. Once a default condition occurs, number 8's will appear and begin flashing in the Deco Status and No Deco Time windows. Once a default is permanent, all decompression calculations will be disabled. Computek will not display any dive planning information during the following surface interval, nor any decompression information in a following dive. Instead, Computek will require a continuous 20 hour surface interval before returning to normal operation

4) The manual is not complete nor is it organized in a manner that makes it easy to follow.

Software versions:

Tekna-Hahn

Accessories / Support Material:

none at this time

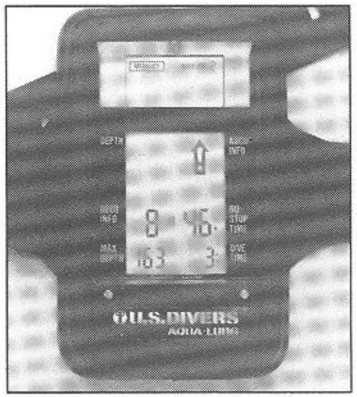
Cost/Warranty:

Console $ 650

Warranty: 2 Year: This warranty does not cover damage or defect due to misuse, alteration, negligence, or accident: nor does it cover damage or defect due to repair by someone other than Tekna. This warranty does not cover batteries. This warranty is not transferable to any owner other than the one identified on the registration card.

U.S. Divers **Data Scan 2** *(see DataMaster II)*

U.S. Divers' **Monitor I**



The Monitor I is the economy version of the Monitor series dive computers. U.S. Divers introduced the Monitor I in 1990. This model identical to Aladin Sport, except the display has a different and larger configuration. Made by Uwatec of Switzerland, the Model Based Monitor I uses the Uwatec's newest version of the Buhlmann ZHL-16 Swiss Model. Like other Swiss dive computers, the Monitor I provides more conservative no-decompression limits than other non-Swiss Models. There are 6 compartments with a half-time range from 6 to 320 minutes. The Monitor I automatically adjusts to any altitude *(to 13,200 feet)* because it senses continuously through-out the life of its batteries. This is considered a no-decompression dive computer with maximum calculations to 330 feet.

Construction:

The Monitor I is made of Lexan Poly carbonate material. The display screen is larger than most at 1 1/2" wide and 2 3/4" high. The display face is covered by a clear flexible Lexan film. Care should be taken in protecting this type of screen from heavy abrasion *(See Gage-Gard accessories later in this chapter).*

Power / Activation

Power to the Monitor I is provided by one 3.6 volt lithium battery. The battery is potted in the case and must be changed through the factory. Manufacturer estimated life of the battery is 6-7 years at 50 dives per year, 5 years at 100 dives per year, 2-3 years at 200 dives per year, 1-2 years at 500 dives per year.

Activation of the Monitor I is by an instant on immersion switch. The Monitor I is completely automated and operates continuously allowing it to adjust to atmospheric changes (including altitude change due to high altitude or flight). Because the Monitor I is constantly on, activation is achieved instantly upon entering the water or by contacting the posts with wet fingers. Time and depth calculations begin after 4 feet of depth.

Features:

- Functional range to 330 ffw
- Depth range to 330'
- Altitude range to 13,200'
- Auto Activation - immersion switch (instant on)
- Logbook
- Dive Plan mode
- Accuracy ±1' ffw
- Calculation every 1 second

Before Dive Displays

- Diagnostic check
- Low battery indicator
- No decompression scrolling 30'-140'
- Surface power down (Power saving deactivation)
- Log book mode
- High altitude sector
- Adaption time
- No flying indicator

During Dive Display

- Current depth
- Maximum depth
- Total elapsed time
- No decompression time remaining
- Decompression stop depth
- Ascent rate indicator
- Ascent indicator for decompression
- Out of range - omitted decompression

After Dive Display

- Maximum depth
- Total dive time
- Surface interval time (in dive plan mode)
- Desaturation time
- New no-decompression limits (in dive plan mode)
- High altitude sector
- Decompression omitted
- Tissue type affected
- Low battery indicator

Log Book

- 9 dives stored
- Dive number shown
- Dive time

- Maximum depth
- Surface intervals
- High altitude sector
- Decompression omitted
- Ascent rate violation

Remarks / Limitations

1) There is no total ascent time given. If a decompression profile is indicated, the Monitor I will not give total time required to the surface nor will it give you the required time at each stop — Not a total decompression dive computer.
2) The wait to fly indicator does not indicate how long to wait before flying. The Monitor I must be monitored until the no flying icon fades from display.
3) The Monitor I must be put in the "DIVE PLAN" mode for it to show no-decompression limits and surface interval. It does not automatically scroll these limits as most other dive computers do.

Software versions:

ZHL-16 updated.

Accessories / Support material

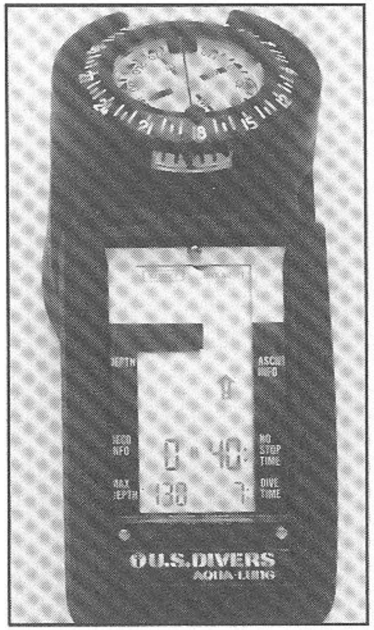
3 console models available

Cost / Warranty:

Wrist	$ 550
Console	$ 680

Warranty: 12 months: Servicing or tampering by any unauthorized parties will invalidate the warranty. This applies equally to the replacement of the battery. The buyer shall not subject the unit to "Dry" pressure testing. Any such testing must only be carried out with the unit submersed in water. Repair under warranty will not apply to any unit which has been subjected to severe shock or abuse, and not maintained in accordance with the care instructions.

U.S. Divers' **Monitor II**



Identical to the Aladin Pro in features, U.S. Divers' Monitor II, was introduced to the U.S. by U.S. Divers in late 1989 *(also made by Uwatec)*. This is truly a professional dive computer with all of the bells and whistles (and alarms in this case) like the Aladin Pro. The Monitor II is designed with advanced divers in mind and has several additional features that the Monitor I doesn't have, including waiting time prior to flying, total ascent time, decompression stop time, and an acoustic alarm for ascent rate or decompression violations. This multi-level Swiss Model dive computer uses the newest version of Buhlmann's ZHL-16 tables and is also manufactured in Switzerland by Uwatec. There is less time at depth because of the more conservative approach of these tables *(see Aladin)*. The Monitor II uses 6 compartments with half-time ranges from 6 to 320 minutes.

This is the one of the best high altitude dive computers on the market and it can be used to altitudes of 13,200 feet as either a desaturated dive computer or as a repetitive dive computer at altitude which calculates at a higher saturation level *(see Aladin Pro)*.

Construction:

The Monitor II is made of the same sealed Lexan Polycarbonate casing as the Monitor I. The screen should be protected from abrasion in all these models *(see Gage-Gard accessories for screen protectors)*.

Power / Activation:

Power specifications is identical for all Monitor models, using one 3.6 volt lithium battery. The battery is potted in the case and must be changed through the factory. Manufacturer estimated life of the battery is 6-7 years at 50 dives per year, 5 years at 100 dives per year, 2-3 years at 200 dives per year, 1-2 years at 500 dives per year.

Activation of the Monitor II is immediate with an immersion type switch. The Monitor II is a "Live" dive computer constantly monitoring atmospheric pressure. Activation depth is 4 feet for calculations.

Features:

- Functional depth range to 330 ffw
- Depth range to 330'
- Altitude range to 13,200'
- Log book
- Dive plan mode – not a simulator
- Accuracy ±1' ffw
- Calculation every 1 second
- Auto activation (immersion switch)

Before Dive Displays:

- Diagnostic check
- Low battery indicator
- No decompression scrolling 30'-140'
- Surface power down (Power saving deactivation)
- Log book mode
- No flying indicator
- High altitude adaptation time
- High altitude sector
- Waiting time prior to flying

During Dive Displays:

- Current depth
- Maximum depth
- Total elapsed time
- No decompression time remaining
- Decompression stop depth
- Decompression stop time
- Total ascent time
- Ascent rate indicator
- Acoustic ascent rate alarm
- Ascent indicator for decompression
- Descent warning for ceiling violation
- Acoustic ascent alarm for decompression
- Out of range – omitted decompression

After Dive Display:

- Maximum depth
- Total dive time
- Surface interval time
- Desaturation time
- No flying icon
- Waiting time prior to flight
- New no-decompression limits (in dive plan)

- High altitude sector
- Decompression omitted
- Tissue type affected
- Low battery indicator

Log Book:
- 9 dives
- Dive number shown
- Dive time
- Maximum depth
- Surface intervals
- High altitude sector
- Ascent rate violation
- Decompression omitted

Remarks / Limitations

1) The best of the U.S. Divers' line and one of the most sophisticated dive computers on the market. A very good choice for advanced divers.
2) Waiting time prior to flight is several hours shorter than Spencer No-D Limits Models. Time to fly is based on 8,000 feet altitude. We recommend to add at least 6 hours to the Monitor II time to fly times.
3) A excellent dive computer for high altitude, decompression, or repetitive diving.

Software versions:

ZHL-16 Updated.

Accessories / Support Material:

3 console models

Cost/Warranty:

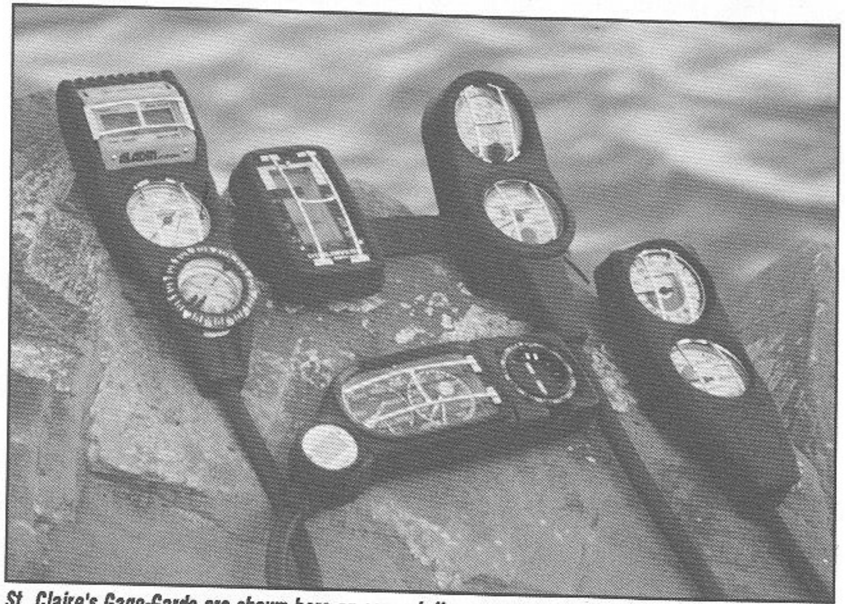
Wrist	$ 660
Console 1	$ 780

Warranty: 12 months: Servicing or tampering by any unauthorized parties will invalidate the warranty. This applies equally to the replacement of the battery. The buyer shall not subject the unit to "Dry" pressure testing. Any such testing must only be carried out with the unit submersed in water. Repair under warranty will not apply to any unit which has been subjected to severe shock or abuse, and not maintained in accordance with the care instructions.

Accessories

Dive computer accessories are rather limited at this time and most come directly from the dive computer distributor or manufacturer. There are, however, some new products emerging to specifically support dive computers. A company that seems to have found a niche in furnishing protective display screen covers is St. Claire of Mill Valley, California.

St Claire's new protective covers, called Gage-Gard, are made of non-magnetic stainless steel. These gauge lens protectors easily slip into console boots or over wrist model dive computers in seconds. The Gage-Gard consists of a stainless steel wire frame-work that



St. Claire's Gage-Gards are shown here on several dive computer models.

raises slightly above the display screen and protects it from abrasion. This frame-work is very similar to a cage and it allows you to view the display screen without interference. Gage-Gard screen protectors are currently available for all dive computer models. We recommend the product for almost all of the dive computers listed in this book *(see individual dive computer overview for recommendation).*

Comparison Charts

The following pages contain dive computer comparison charts that can be used as a quick reference comparison guide. These charts contain information that was derived from the dive computer manual, and/or directly from the manufacturer or distributor. In some cases the dive computer's manual may give incorrect information (typically when they convert from Metric to English units) and we have re-converted those units.

Computer Depth Limitations

Table 8-2

Dive Computer	Full Function Range	Depth Gauge Range	NDL Limits Scrolled	Ascent Rate (Feet per Minute)	Activation Depth	Accuracy (+ / -)
Beuchat Aladin	330'	330'	NONE	33	4'	1.5 ffw
Beuchat Aladin Sport	330'	330'	30' - 140'	33	4'	1.5 ffw
Beuchat Aladin Pro	330'	330'	30' - 140'	33	4'	1.5 ffw
Dacor Micro Brain	270'	330'	51' - 130'	33 - 40	5'	1' fsw
Dacor Micro Brain Pro Plus	270'	330'	41' - 149'	33 - 40	5'	1' fsw
Mares Mentor	199'	199'	30' - 130'	60 - 40 - 20	6.1'	1.5 fsw
Oceanic DataMaster II	138'	249'	30' - 130'	60	7'	+1%, -0% fsw
Oceanic DataMaster Sport/S	167'	249'	30' - 160'	60 - 40 - 30	7'	+1%, -0% fsw
Oceanic DataMax Sport	167'	249'	30' - 160'	60 - 45 - 30	5'	1% fsw
Orca Mark II	199'	199'	30' - 130'	60 - 40 - 20	6.1'	1.5 fsw
Orca Edge	170'	170'	30' - 150'	60 - 40 - 20	6.6'	1.5 fsw
Orca Delphi	199'	199'	30' - 130'	60 - 40 - 20	6.1'	1.5 fsw
Parkway Legend	330'	330'	30' - 140'	33	4'	1.5 ffw
Scubapro DC-11	300'	300'	41' - 149'	33 - 50	5'	.3 fsw
Scubapro Dive Vu	300'	300'	30' - 300'	60	5'	1 fsw
Sherwood Sigmatech II	199'	199'	30' - 130'	60 - 40 - 20	6.1'	1.5 fsw
Sherwood Source	167'	249'	30' - 160'	60 - 45 - 30	7'	1% fsw
Suunto SME-ML R 1	200'	230'	30' - 190'	33	5'	3.45 fsw
Suunto Solution	325'	325'	30' - 150'	33	5'	1% fsw
Tekna Computek	160' 220' *	220'	30' - 130'	33	7'	1 fsw
U.S. Divers DataScan 2	138'	249'	30' - 130'	60	7'	+1%, -0% fsw
U.S. Divers DataScan 3	167'	249'	30' - 160'	60 - 40 - 30	7'	+1%, -0% fsw
U.S. Divers Monitor I	330'	330'	30' - 140'	33	4'	1.5 ffw
U.S. Divers Monitor II	330'	330'	30' - 140'	33	4'	1.5 ffw

* In decompression range fsw = feet salt water ffw = feet fresh water

Table 8-3

Computer Operational Limitations

Dive Computer	Dive Timer Range (in minutes)	Dive Counter Range	Calculation Rate per Min.	Decompression Limits	Operation Temperature	Altitude Range
Beuchat Aladin	999	5 *	60	80'+	14° - 122° F	13,200' **
Beuchat Aladin Sport	199	9 *	60	80'+	14° - 122° F'	13,200' **
Beuchat Aladin Pro	199	9 *	60	80'+	14° - 122° F	13,200' **
Dacor Micro Brain	199	6 *	12 / 60D	78'	14° - 122° F	6,560'
Dacor Micro Brain Pro Plus	199	6 *	12 / 60D	98'	14° - 122° F	6,560'
Mares Mentor	199	3 *	20	186.5'	24.8° - 122° F	10,000'
Oceanic DataMaster II	599.98	9	60	12'	32° - 150° F	2,000'
Oceanic DataMaster Sport	599.98	9	60	20'	32° - 150° F	2,000'
Oceanic DataMax Sport	599.98	9	60	30'	32° - 150° F	3,000'
Orca Mark II	199	1	20	186.5'	24.8° - 122° F	2,000'
Orca Edge	99.98	1	20	157.5'	16.8° - 123° F	2,000'
Orca Delphi	199'	3 *	20	186.5'	24.8° - 122° F	10,000'
Parkway Legend	199	9 *	60	80'+	14° - 122° F	13,200'
Scubapro DC-11	199	6 *	60	70'	14° - 122° F	13,200'
Scubapro Dive Vu	199	20 hours	60	65'	14° - 122° F	20,000'
Sherwood Sigmatech II	199	1	20	186.5'	24.8° - 122° F	2,000'
Sherwood Source	599.98	9	60	30'	32° - 150° F	3,000'
Suunto SME-ML R 1	999	10	20 / 60D	90'	32° - 104° F	1,600'
Suunto Solution	999	10	20 / 60D	140'	32° - 104° F	8,200'
Tekna Computek	199	10	60 / 10Dec	40'	15° - 99° F	10,000'
U.S. Divers DataScan 2	599.98	9	60	12'	32° - 150° F	2,000'
U.S. Divers DataScan 3	599.98	9	60	20'	32° - 150° F	2,000'
U.S. Divers Monitor I	199	9 *	60	80'+	14° - 122° F	13,200'
U.S. Divers Monitor II	199	9 *	60	80'+	14° - 122° F	13,200'

* = In log book mode ; ** = Manual information is 13,000', however, it is incorrect (4,000 meters = 13,200 feet) ; D = calculations for depth
Dec = Calculations for Decompression

Display Features Prior To Diving

Table 8-4

Dive Computer	Diagnostic Check	Software Version Indicator	Remaining Battery *Indicator*	Low Battery Indicator	NDL Scrolling	Auto Deactivation	Ambient Pressure Indicator	Temperature Display	Cylinder Pressure	Log Book Feature
Beuchat Aladin	X			X		X	X			X
Beuchat Aladin Sport	X			X	X	X	X			X
Beuchat Aladin Pro	X			X	X	X	X			X
Dacor Micro Brain	X	X			X	X				X
Dacor Micro Brain Pro Plus	X	X			X	X				X
Mares Mentor	X	X	X	X	X	X	X	X	X	X
Oceanic DataMaster II	X			X	X	X		X	X	
Oceanic DataMaster Sport/S	X			X	X	X		X	X	
Oceanic DataMax Sport	X			X	X	X				X
Orca Mark II	X	X	X	X	X	X	X			
Orca Edge	X	X		X	X			X		
Orca Delphi	X	X	X	X	X	X	X	X	X	X
Parkway Legend	X			X	X	X	X			X
Scubapro DC-11	X	X		X	X	X	X*	X		X
Scubapro Dive Vu	X	X		X	X	X	X	X	X	X
Sherwood Sigmatech II	X	X	X	X	X	X	X			
Sherwood Source	X			X	X	X				X
Suunto SME-ML R1	X	X		X	X	X				X
Suunto Solution	X			X	X	X	X*	X		X
Tekna Computek	X		X	X	X	X		X	X	X
U.S. Divers DataScan 2	X			X	X	X			X	
U.S. Divers DataScan 3	X			X	X	X			X	
U.S. Divers Monitor I	X			X	X	X	X			X
U.S. Divers Monitor II	X			X	X	X	X			X

* User selectable altitude range

Log Book Display Features

Table 8-5

Dive Computer	Number of Dives Stored	Dive Time	Dive Number Counter	Surface Interval	High Altitude Record	Maximum Depth	Max. Depth Ever Reached	Total Dive Time Hours	Total # of Dives	Dive Profile Recall	Exceeded Warnings	Decompression Omitted
Beuchat Aladin	5	X	X	X	X	X						
Beuchat Aladin Sport	9	X	X	X	X	X					X	X
Beuchat Aladin Pro	9	X	X	X	X	X					X	X
Dacor Micro Brain	3/6**	X				X						
Dacor Micro Brain Pro Plus	3/6**	X	X	X		X	X	X	X			
Mares Mentor	3	X	X	X		X	X*	X*	X*	X*	X*	X*
Oceanic DataMaster II												
Oceanic DataMaster Sport/S												
Oceanic DataMax Sport	7	X	X			X						
Orca Mark II												
Orca Edge												
Orca Delphi	3	X	X	X		X	X*	X*	X*	X*	X*	X*
Parkway Legend	9	X	X	X	X	X					X	X
Scubapro DC-11	3/6**	X	X	X		X	X	X	X			
Scubapro Dive Vu	20hrs.	X	X	X	X	X	X	X	X	X	X	X
Sherwood Sigmatech II												
Sherwood Source	7	X	X			X						
Suunto SME-ML R1	10 hrs.	X	X	X		X				X		
Suunto Solution	8 hrs.	X	X	X		X	X	X	X	X	X	X
Tekna Computek	10 **	X	X	X		X						
U.S. Divers DataScan 2												
U.S. Divers DataScan 3												
U.S. Divers Monitor I	9	X	X	X	X	X					X	X
U.S. Divers Monitor II	9	X	X	X	X	X					X	X

* In DataLogger recall ** Until desaturation

Table 8-6

Dive Computer	Current Depth	Maximum Depth	Elapsed Time Underwater	No-Deco Time Remaining	Decompression Warning (ascend)	Decompression Stop Depth	Decompression Depth Range To	Out of Deco Depth Warning	Decompression Stop Time	Deco Stop Time Range
Beuchat Aladin	X	X	X	X	X	X	80'+	X		
Beuchat Aladin Sport	X	X	X	X	X	X	80'+	X		
Beuchat Aladin Pro	X	X	X	X	X	X	80'+	X	X	99 min.
Dacor Micro Brain	X		X	X*	X	X	98'	X		
Dacor Micro Brain Pro Plus	X		X	X*	X	X	78'	X	X	90 min.
Mares Mentor	X		X	X	X	X	187.5'	X	X	199 min.
Oceanic DataMaster II	X	X	X	X	X	X	12'		X	10 min.
Oceanic DataMaster Sport/S	X	X	X	X	X	X	20'		X	10 min.
Oceanic DataMax Sport	X		X**	X	X	X	30'	X	X	599 min.
Orca Mark II	X		X	X	X	X	186.5'	X		
Orca Edge	X	X*	X	X	X	X	157.5'	X	X	99 min.
Orca Delphi	X		X	X	X	X	187.8	X	X	199 min.
Parkway Legend	X	X	X	X	X	X	80'+	X	X	99 min.
Scubapro DC-11	X	X	X	X	X	X	70'+	X	X	90 min.
Scubapro Dive Vu	X	X	X	X	X	X	65'	X	X	199 min.
Sherwood Sigmatech II	X		X	X	X	X	187.5'	X		
Sherwood Source	X		X**	X	X	X	30'	X	X	599 min.
Suunto SME-ML R 1	X	X*	X	X	X	X	90'	X	X	30 min.
Suunto Solution	X	X	X	X	X	X	140'+	X	X	99 min.
Tekna Computek	X	X	X	X	X	X	40'	X	X	45 min.
U.S. Divers DataScan 2	X	X	X	X	X	X	12'		X	10 min.
U.S. Divers DataScan 3	X	X	X	X	X	X	20'		X	10 min.
U.S. Divers Monitor I	X	X	X	X	X	X	80'+	X		
U.S. Divers Monitor II	X	X	X	X	X	X	80'+	X	X	99 min.

* Displayed Graphically ** Every 10 seconds

Table 8-6

Display Features During The Dive

Dive Computer	Descend To Deco Stop	Total Ascent Time	Ascent Rate Warning	Audible Alarms	Out of Range (Depth)	Out of Range (Deco)	Dive Number	Remaining Air Time	Cylinder Pressure	Temperature Display
Beuchat Aladin	X									
Beuchat Aladin Sport	X		X							
Beuchat Aladin Pro	X	X	X	X						
Dacor Micro Brain	X		X			X				
Dacor Micro Brain Pro Plus	X	X	X			X				
Mares Mentor	X	X	X		X			X	X	X
Oceanic DataMaster II					X	X	X	X	X	X
Oceanic DataMaster Sport/S			X		X	X	X	X	X	X
Oceanic DataMax Sport	X		X		X	X	X			
Orca Mark II	X		X		X					
Orca Edge	X	X*	X*		X					X
Orca Delphi	X	X	X		X			X	X	X
Parkway Legend	X	X	X	X						
Scubapro DC-11	X	X	X		X	X				X
Scubapro Dive Vu	X	X	X			X		X	X	X
Sherwood Sigmatech II	X		X		X				X	
Sherwood Source	X		X		X	X	X			
Suunto SME-ML R 1	X		X		X	X	X			
Suunto Solution	X	X	X	X	X	X	X			X
Tekna Computek	X	X	X	X		X	X	X	X	X
U.S. Divers DataScan 2					X	X	X	X	X	
U.S. Divers DataScan 3			X		X	X	X	X	X	
U.S. Divers Monitor I	X		X							
U.S. Divers Monitor II	X	X	X	X						

* DIV 6

Display Features After Diving

Table 8-7

Dive Computer	Maximum Depth	Elapsed Time Underwater	Surface Interval Time	New No-Deco Limits	Dive Number Counter	Desaturation Time	Do Not Fly Indicator	Time To Fly	Out of Range Shut-Down	Temperature Display
Beuchat Aladin	X	X	X							
Beuchat Aladin Sport	X	X	X	X		X	X			
Beuchat Aladin Pro	X	X	X	X		X	X	X		
Dacor Micro Brain	X	X		X			X		X	
Dacor Micro Brain Pro Plus	X	X	X	X		X	X	X	X	
Mares Mentor	X	X	X	X				X		X
Oceanic DataMaster II	X	X	X	X	X				X	X
Oceanic DataMaster Sport/S	X	X	X	X	X				X	X
Oceanic DataMax Sport	X	X	X	X	X	X*	X*		X	
Orca Mark II	X	X	X	X				X		
Orca Edge	X	X	X	X		X*	X	X**		X
Orca Delphi	X	X	X	X		X*		X		X
Parkway Legend	X	X	X	X		X	X	X		
Scubapro DC-11	X	X	X	X		X	X	X	X	X
Scubapro Dive Vu	X	X	X	X			X			X
Sherwood Sigmatech II	X	X	X	X				X		
Sherwood Source	X	X	X	X	X	X*			X	
Suunto SME-ML R1	X	X	X	X	X		X		X	
Suunto Solution	X	X	X	X	X	X	X	X	X	X
Tekna Computek	X	X	X	X	X		X		X	X
U.S. Divers DataScan 2	X	X	X	X	X				X	
U.S. Divers DataScan 3	X	X	X	X	X				X	
U.S. Divers Monitor I	X	X	X	X		X	X			
U.S. Divers Monitor II	X	X	X	X		X	X	X		

* Displayed Graphically ** DIV 6

Chapter 9

High Altitude Diving & Flying After Diving

Altitude Diving

Most of the instructional agencies define altitude diving as any diving that occurs at altitudes greater than 1,000 feet. In addition, altitude diving is considered a specialty area of diving that requires specific training. There are special considerations including altitude tables and detailed procedures that must be followed when diving at high altitudes. These special considerations are the result of decreasing ambient pressure at increasing altitude.

All of the computers have their own unique altitude diving capabilities and some of the computers are actually designed to function specifically under the conditions encountered during altitude diving. The importance of advanced training for altitude diving can not be overemphasized even though each dive computer may give directions for using the device at altitude.

The altitude capabilities or limits of each dive computer will be discussed inside this chapter. This information is the result of many hours of high altitude dive testing performed by Danny Rossi. Following is Rossi's conclusions:

Diving at higher elevations implies diving with reduced atmospheric pressure at the surface. Because of this, several considerations need to be taken into account with respect to the use of dive tables or dive computers at altitude.

First, as the diver travels to the high altitude dive site from a lower elevation, there will be a certain amount of excess nitrogen pressure in the tissues *(with respect to the lower ambient partial pressure)*. This is the same as saying that there will be "residual nitrogen" in the divers body. Therefore there will be a "desaturation or adaptation time" before the first dive can be considered non-repetitive, otherwise this residual nitrogen has to be taken into account in the dive planning.

Second, the reduced atmospheric pressure at the surface will translate into shorter No-Stop times for the different depths, with corresponding reductions also on the ascent rates and equivalent safety stops depths.

Finally, instrumentation errors may need to be taken into account, as many depth gauges are designed and calibrated to read zero feet on the surface at sea level, with no provisions for corrections for altitude use.

Using Dive Computers at High Altitude

When considering using a dive computer for high altitude diving *(within its specified range)*, there are three possibilities to consider:

a) the dive computer fully compensates for altitude by indicating the correct depth and the reduced No-Stop times, while also calculating and taking into account the "adaptation time";

b) the dive computer compensates for altitude by indicating the correct depth and reduced No-Stop times, but with the assumption that the diver has fully "adapted" to the new altitude prior to the first dive (i.e. no "residual nitrogen" in the divers' body);

c) the dive computer compensates for the altitude by indicating the correct depth and time only, with all the other decompression requirements to be calculated by the diver using a suitable dive table.

The first place to look for information as to a dive computers' high altitude capabilities is, of course, the user's manual. The manufacturer will usually include at least a statement of the altitude

limitations, but in many cases a lot more information will be provided. The information provided may be sufficient to identify if a particular dive computer falls into any of the three categories identified above.

Diving in 40 lakes of California, from Shaver Lake at 5,500 feet to Saddlebag at an altitude of just over 10,000 feet, confirmed the indicated performance on some dive computers and also showed some interesting surprises.

The test dives ranged in time from 21 to 92 minutes with depths from 12 to 160 feet.

Note: Depth indications were compared against a temperature-compensation digital instrument with an altitude range of up to 14,800 feet. Its depth calibration was checked against true depth measured by an inelastic line. The instrument read and indicated atmospheric pressure in millibars at power on. This indication was checked against a barometer at the different dive sites.

Beuchat's **Aladin** & **Aladin Pro**
U.S. Divers' **Monitor I** & **Monitor II**

Four different computers, the Aladin, Aladin Pro and the Monitor I and II fall into possibility a), as above. The Aladin does require being switched "on" prior to the first dive, but the other three computers are always ready to be taken diving provided that no altitude change has occurred within the last 35 minutes.

As expected, these four dive computers performed very well, as our diving was within their specified altitude range *(13,200 feet)*. On some occasions, the Aladin computer would not readily "sense" *(with its on/off switch)* the fresh water, and required a cleaning of the contacts to turn it on. When the computer did not properly detect the fresh water, errors in selecting the altitude range were occasionally observed.

The available No-Stop times indicated by these dive computers would get longer as we allowed more surface time prior to our dive, as "adaptation time" ticked away. The only exception to these was the Aladin, which needed to be switched "on" within ten minutes prior to the first dive, therefore the computer always assumed that the diver had just arrived at that altitude *(No credit being given for time spent at altitude before first dive)*.

After the dives, in many cases there was no indication of Time to Fly on the Aladin Pro and the Monitor II; for example after diving in lakes at 9,600 feet. Also, when travelling to lower elevations after diving, the desaturation time indicated by these two computers would diminish by more than the time elapsed. In many cases, when travelling to a lower elevation zone, the computers would indicate that it was no longer in a repetitive dive mode, by switching off *(Indicating complete desaturation to the new elevation)*.

Beuchat's **Aladin Sport**

As with all of the Beuchat computers, the Aladin Sport falls into possibility a), as above. The dive computer fully compensates for altitude by indicating the correct depth and the reduced No-Stop times, while also calculating and taking into account the "Adaptation Time". The Aladin Sport does not require switching "on" prior to the first dive and is always ready to be taken diving provided that no altitude change has occurred within the last 35 minutes.

As expected, this dive computer performed very well as our diving was within the specific altitude range *(13,200 feet)*. The available No-Stop times indicated by this dive computer would get longer as we allowed more surface time prior to our first dive, as "Adaptation time" ticked away.

As expected after some of the test dives, in many cases there was no "Do Not Fly" indication on the Aladin Sport, for example after diving in lakes higher than 8,200 feet. Also, when traveling to lower elevations after diving, the Desaturation Time indicated by this dive computer would diminish by more than the time elapsed. In many cases, when travelling to a lower elevation zone, the computer would indicate that it was no longer in a repetitive dive mode, by switching off *(Indicating complete desaturation to the new elevation)*.

Dacor's **Micro Brain** & **Micro Brain Pro Plus**

Two dive computers, the Micro Brain and the Micro Brain Pro Plus, fall into possibility b) as above. With these two dive computers, no adaptation time is required up to 4,920 feet. Beyond this level and up to 6,560 feet the adaptation time will depend upon your starting elevation. At altitudes higher than 6,560 feet, the depth indication will remain correct up to 19,685 feet for the Micro Brain and up to 14,764 for the Micro Brain Pro Plus.

The user's manuals for these two dive computers provide all the necessary information regarding the times the divers must wait, at altitude, before diving *(This is so that No-Stop times indicated by the computers are valid)*.

The No-Stop times given by these two computers are the same at altitude as at sea level. The fact that these No-Stop times have been adjusted for diving up to 4,920 feet with no corrections gives an indication of the extra safety margin that these two computers provide when diving at sea level.

These two dive computers performed well, once I could get them switched on to the "dive "mode. Almost always I had some trouble getting the computers to activate once in the *(fresh)* water, the problem being worse after a series of dives in the ocean and then doing fresh water dives. The solution I found to this inconvenience was to always clean the contacts prior to my first fresh water dive, using an eraser. The gold contacts on the Micro Brain Pro Plus are a definite improvement, but cleaning was still required.

Oceanic's **DataMaster II, DataMaster Sport** & **DataMax Sport**
U.S. Divers' **Data Scan 3**

All of these dive computers fall into possibility c) as above. They need to be switched "on" once the diver is at the dive site, so that the computers would indicate the true depth, compensating for the high altitude. The computers now act as precision timer-depth gauge combinations, no longer providing any decompression information.

As the user's manuals indicate, all these dive computers performed well up to 10,000 feet of altitude, the depth indications being well within the specified tolerance of one percent. The computers are "salt water" calibrated, so that in fresh water the indicated depth will be slightly less than line measured depth.

An unexpected surprise was that the DataMax Sport had no maximum depth recorded in the log. After dives at altitude for dive times between 30 and 51 minutes and depths from 35 to 55 feet, its log showed the correct dive times but a pair of flashing zeros for maximum depth for each dive.

One other shortcoming shared by all of these four computers concerns changing the dive site after the first dive. While the computer is still on, it does not again measure

atmospheric pressure. What this means is that, when travelling to a different *(say lower)* elevation lake, upon arrival, the computer would already be indicating a depth different than zero *(two to three feet)*. In one case this caused the console mounted computer to start counting dive time during the surface swim — the extra three or four feet of depth due to being at the end of the hose was sufficient to reach the seven feet activation depth of the dive timer.

In the case of the DataMax Sport, the four/five feet activation depth of the dive timer made this dive computer more prone to start timing a dive while still on the surface. In the worst case, which happened often when diving lakes higher than 8,000 feet, upon travelling to a dive site at a lower elevation the pressure difference would be sufficient to start the computer on the next dive — all by itself! — indicating five feet of depth. In one extreme case, a depth of eleven feet was indicated, when travelling back to sea level from a high altitude lake dive.

When this happens, the dive computers will continue on their own dive until the dive time exceeds the maximum of ten hours and after an additional period of time the computer will switch off. While this is generally not a problem in most of real life lake diving, it does point to the need to not switch "on" your computer until the dive site has been reached.

Suunto's **SME ML**

This dive computer falls into possibility c), as above. The user's manual indicates as a maximum operational range 1,600 feet above sea level. It needs to be switch "on" once the diver is at the dive site, so that the computer would indicate the true depth, compensating for the high altitude.

Surprisingly, the computer did compensate, indicating correct depths for altitudes up to 7,000 feet. Being calibrated in feet of sea water *(instead of fresh water)*, the depth indications were always less than true depth, but well within the instruments' specified tolerance of +/-3.5 feet.

The computer will continue to provide No-Stop times even at this higher altitudes, but this information must be ignored, since the numbers would not be correct. Even the "Do Not Fly" indication would appear after a dive at 8,000 feet of altitude! But the nice thing is that it provides proper depth and dive times, together with the corresponding logbook functions.

The dive computer performed very well in fresh water, always activating properly. For the record, some error in the depth indication *(about three to four feet shallower than true depth)* started to show up at around 8,000 feet of altitude; and the indication was definitely out of tolerance at 9,000 feet *(more than five feet of error)*.

Orca's **Edge** & **SkinnyDipper Mark II**

These two dive computers also fall into possibility c), as above. The user's manual indicates altitude limits for the decompression algorithm of 2,000 feet. But as a precision depth gauge and timer, the edge will work up to around 12,000 feet, while the Mark II will indicate correct depths even at altitudes as high as 18,000 feet.

The computers will continue to provide No-Stop times even at this higher altitudes, but this information must be ignored, since the numbers would not be correct. But the nice thing is that they provide proper depth and dive times, together with the corresponding logbook functions. Orca Industries suggests using the depth and time indications provided by the dive computers with the E.R. Cross corrections *(high altitude corrected dive tables)* to the U.S. Navy tables.

Both the Edge and the Mark II performed very well at altitude with accurate depth indication (salt water depth calibration). For high altitude diving, the manual "ON/OFF" switch that these dive computers have now becomes a very useful asset. It allows them to be switch off and re-initialized in the case of travelling to a different elevation lake site. In this way, an accurate surface reference pressure can always be obtained, despite the fact that the computers do not measure the atmospheric pressure again as long as they are still "ON". The loss of residual nitrogen information is no longer a factor, since the decompression algorithm is limited to 2,000 feet and the computer is now being used as a precision depth gauge and timer only.

Orca's **Delphi**
Mares' **Mentor**

These dive computer fall into possibility b), as above. They assume that the diver has been at altitude long enough so as to have no "residual nitrogen" prior to the first dive, due to changes in altitude.

The computers compensate up to 10,000 feet by providing correct depth indications and adjusted No-Stop Times. The User's Manual states that the diver should wait 48 hours after travelling from low altitude to a high altitude lake.

The dive computers measure the atmospheric pressure only upon power-up. While the computer is still in a repetitive dive mode, travelling to a lower elevation lake made the computer indicate a depth greater than zero at the surface, since the reference atmospheric pressure is not reset until the dive computer switches "OFF". It is also possible for the dive computer to start counting the Dive Time for the next dive while still doing a surface swim, due to the console being at an added three or four feet of depth *(at the end of the HP hose)*.

Since the computers are "salt water calibrated" when diving in fresh water lakes the depth indication is slightly less than true depth. These computers indicate the depth in feet *(or meters)* of salt water provided that the dive computer has been switched on at the dive site elevation.

During our test dives, the dive computers performed well, although we had some problems with the battery life, which was much shorter than specified. Due to the cold water, the Delphi computer would "lock up", usually less than 30 minutes after entering the water with a "Lo Lo" indication. The voltage indicated at lock-up was 7.04 volts. About one minute before locking up underwater, a "Go Up" indication would begin flashing in the display!

Both Lithium and Alkaline type batteries were used during our test dives. The Alkaline type gave an even shorter life than the Lithium type, as expected. But for cold water diving we found that we had to replace the battery as soon as the computer showed a "Lo" indication, so as to be sure of completing the next repetitive dive.

Scubapro's **DC-11**

This computer manufactured by Divetronics for Scubapro provides some unique features such as User Programmable for Sea Level or Altitude Diving (and also depth display in feet or meters). When the Altitude program is selected, then the dive computer falls into possibility a) above. This dive computer fully compensates for altitude by indicating the correct depth and the reduced No-Stop times, while also beginning to time off a 17-hour "Adaptation Time". This time is based on the assumption that the diver travels from sea level to 11,500 feet of elevation. Therefore it allows diving in mountain lakes of up to that altitude without any additional waiting period.

If the diver waits for 24 hours at an elevation of at least 9,900 feet, then the range of the computer in the Altitude mode extends to 13,200 feet. As a precision timer and depth gauge only, *(possibility c), as above)*, the dive computer compensates up to 14,800 feet of altitude retaining all of its logbook and Dive Recorder functions.

With this dive computer the diver has to select the Altitude Program, it is not done automatically by the computer upon power up, as is the case with other dive computers that compensate for altitude diving. On the other hand, this allows the computer to be safely used in a rental program from a High Altitude dive site, since a travelling diver may not have fully adapted to the elevation while the computers rented on location would assume complete adaptation due to their being there for days or weeks!

During our test dives the computer performed very well, with a depth indication accuracy claimed of one third of a foot! This resolution was better than that of our other instruments and rope measurement errors.

No problems were encountered in getting the computer to switch on to the "dive" mode upon immersion in the water. The gold contacts certainly are a big help although proper cleaning of them is certainly a good practice.

The No-Stop Times displayed were amongst the most conservative of all of the dive computers tested, Particularly for repetitive dives, faster ascents or dives that included even small amount of re-descents to deeper depths.

Tekna's **Computek**

This dive computer falls into possibility b), as above. It assumes that the diver has no "residual nitrogen" prior to the first dive due to changes in altitude.

The computer compensates up to 10,000 feet by providing correct depth indications and adjusted No-Stop Times. The adjustment of the available No-Stop Times is continuous *(in contrast to several discrete "Altitude ranges")*. These numbers are re-calculated whenever a drop in surface pressure equivalent to about one foot of sea water is detected by the computer. This means that any increment of altitude higher than about 900 feet above sea level would correspondingly start showing a reduction of the indicated No-Stop Times.

The Computek performed well at altitude; the No-Stop times displayed being amongst the most conservative of all the Dive Computers tested.

Surprisingly, after the dives at altitudes higher than 8,000 feet the computer still indicated that flying was not allowed, usually for a few minutes after surfacing (typically less than 15 minutes). This is probably due to numerical rounding off and delays in the recalculations of compartment pressures.

This dive computer measures the atmospheric pressure only upon power-up. While the computer is still in a repetitive dive mode, travelling to a lower elevation lake made the computer indicate a depth greater than zero at the surface, since the reference atmospheric pressure is not reset until the dive computer switches "OFF". It is also possible for the dive computer to start counting the Dive Time for the next dive while still doing a surface swim, due to the console being at an added three or four feet of depth *(at the end of the HP hose)*.

After diving a high altitude lake and then travelling to sea level the Computek would start on a dive of its own, when the pressure difference reached seven feet. This dive continued until the battery was removed *(the unit could also have been taken back to a higher elevation)*. Although this is an unlikely occurrence, when the dive computer was stored in a dive bag the backlight turned "ON", further increasing the battery drain. Since the battery is user replaceable, this is not a major inconvenience *(unless the diver fails to notice that the computer is still "ON")*. Nevertheless, the battery life observed was very good. Despite the cold water of most of the test dives we never had to replace the battery.

Conclusions

The results of extensive testing of currently available dive computers' performance in high altitude diving has been presented. This information should help the diver assess how a particular model

Dive Computer High Altitude Information

Dive Computer	Full Compensation	No-Stop time Compensation	Depth Compensation	Maximum Depth	No-Stop Time	Adaption Time	Dive Time
Beuchat Aladin	13,200'	13,200'	13,200'	Yes	Yes	No	Yes
Beuchat Aladin Sport	13,200'	13,200'	13,200'	Yes	Yes	Yes	Yes
Beuchat Aladin Pro	13,200'	13,200'	13,200'	Yes	Yes	Yes	Yes
Dacor Micro Brain	4,920'	6,560'	19,685'	Log	Yes	No	Yes
Dacor Micro Brain Pro Plus	4,920'	6,560'	14,764'	Log	Yes	No	Yes
Mares Mentor	2,000'	10,000'	10,000'	Log	Yes	No	Yes
Oceanic DataMaster II	2,000'	2,000'	9,900'	Yes	No	No	Yes
Oceanic DataMaster Sport	2,000'	2,000'	9,900'	Yes	No	No	Yes
Oceanic DataMax Sport	3,000'	3,000'	10,000'	No	No	No	Yes
Orca Mark II	2,000'	2,000'	18,000'	Log	No	No	Yes
Orca Edge	2,000'	2,000'	12,000'	Yes	No	No	Yes
Orca Delphi	2,000'	10,000'	18,000'	Log	Yes	No	Yes
Parkway Legend	13,200'	13,200'	13,200'	Yes	Yes	Yes	Yes
Scubapro DC-11	11,500'	13,200'	14,800'	Yes	Yes	Yes	Yes
Sherwood Source	3,000'	3,000'	10,000'	No	No	No	Yes
Suunto SME-ML R-1	1,600'	1,600'	7,600'	Yes	No	No	Yes
Tekna Computek	1,000'	10,000'	10,000'	Yes	Yes	No	Yes
U.S. Divers DataScan 3	2,000'	2,000'	9,900'	Yes	No	No	Yes
U.S. Divers Monitor I	13,200'	13,200'	13,200'	Yes	Yes	Yes	Yes
U.S .Divers Monitor II	13,200'	13,200'	13,200'	Yes	Yes	Yes	Yes

Note: Full Compensation indicates altitude range for diver NOT adapted to the altitude.

would suit his/her needs.

Even if you currently own a dive computer whose algorithm does not compensate for altitude diving, do no leave it in your dive bag when you go diving in a mountain lake. Most likely it would still give you correct depth and dive time information. Just make sure that you do switch it "on" at the dive site prior to entering the water, to be able to get accurate depth indications.

Flying After Diving

As all divers know, there are some special considerations when flying after diving because of the decreasing ambient pressure that is associated with the increased elevations caused by flying. This reduction in ambient pressure is adequate enough to create havoc

UHMS Flying After Diving Guidelines for Recreational Divers

Dive Schedule for Diver on Air (Diver is without Decompression Sickness Symptoms)	**Surface Interval in Hours Before a Diver Should Fly at Cabin Altitudes up to 8,000 feet**
No-Decompression Dives:	
a. Less than 2 hours total accumulated dive time (surface to surface time) in the last 48 hours	12
b. Multi-day, unlimited diving	24
Dives that Require Decompression Stops:	**24 - 48 ***

* Flying must be delayed for a minimum of 24 hours and, if possible, for 48 hours.

Note: 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. The guidelines above are "best estimates" based on current scientific information and expert opinion, and are expected to be conservative, safe surface intervals for the vast majority of divers. In a few individuals, their physiological makeup or special circumstances of the dives may result in decompression sickness even though the guidelines are followed. These guidelines may be amended in the future as further data and knowledge are developed.

with the nitrogen out-gassing process.

Most commercial airliners pressurize the cabins of the aircraft to maintain an altitude equivalent of between 3,000 feet and 6,000 feet. The maximum allowable cabin pressure altitude, dictated by the FAA, is 8,000 feet. There are, occasionally, instances where some international fights may reduce cabin pressure to an altitude equivalent of 8,000 feet *(the FAA's limit)*. This usually occurs in older aircraft where excessive pressurization tends to cause structural stress.

Over the past several years there have been some recommendations and changes concerning the procedures for flying after diving. A recent workshop conducted by the Undersea and Hyperbaric Medical Society (UHMS) on Flying After Diving (February, 1989) produced these guidelines for recreational divers *(refer to page153)*.

Chapter 10

Decompression Diving First Aid & Treatment

Decompression diving occurs whenever No-Decompression Limits are exceeded. Exceeding these limits requires a diver to make a stop during ascent in order to allow the nitrogen in the tissues to slowly out-gas. Decompression diving is explicitly not recommended by all of the instructional agencies. Any time that a decompression stop is required, a diver has lost the ability to return directly to the surface and, in an emergency such as running out of air, the net result could be disastrous. Furthermore, decompression diving requires advanced planning and preparation and is not an endeavor that should be taken lightly.

Although decompression diving is beyond the realm of sport diving, there are some commercial and scientific divers that perform decompression diving as part of their duties. Accordingly, decompression capabilities of various dive computers are discussed in the dive computer overview section *(Chapter 8)*.

Several of the dive computers that have been discussed in the Dive Computer Overview are actually **No-Decompression** dive computers. This means that they are not intended to be used for decompression diving. All of these dive computers have the capability, however, to aid a diver through an emergency decompression should the diver inadvertently exceed the no-decompression limit.

Decompression dive computers *(see Chapter 8)* have been used by commercial divers and scientific divers for decompression diving because they will show how much time is required for decompression. Note that theoretical models have not been extensively tested for repetitive decompression diving and as a consequence this is probably not an advisable procedure.

Prior to getting into the actual comparison of the decompression capabilities of each of the computers, there are a couple of terms that should be reviewed. The minimum decompression stop depth is often referred to as a ceiling. The ceiling is the shallowest depth to which a diver in a decompression mode may ascend without violating the decompression model. The ceiling is similar to a decompression stop depth, however, it is acceptable to be at a depth that is deeper than the specified ceiling depth. As a matter of fact, there are some experts that recommend decompressing at depths deeper than the ceiling to stay further away from model limits. The only consideration is that at depths deeper than the ceiling the out-gassing of nitrogen will occur at a slower rate *(i.e. the required decompression time will be longer)*. A computer specified ceiling might be at any depth which is in contrast to the Navy tables decompression stop depths that are limited to multiples of 10' increments.

Recognition, First Aid, and Treatment of Decompression Sickness

The best way to deal with decompression sickness, or any diving malady, is to prevent it. In the case of decompression sickness, this should be accomplished by adhering to these three points. First, dive conservatively with respect to the no-decompression limits whether specified by a dive computer or a dive table. Second, do not exceed the prescribed ascent rates. Finally, perform safety stops towards the end of the ascent. It would be worthwhile to review the Guidelines for Using Dive Computers in Chapter 5.

Unfortunately, accidents such as decompression sickness do occur in the diving environment. The administration of proper first aid and subsequent treatment following an incidence of decompression sickness may be paramount to a successful recovery. The steps in the treatment of decompression sickness may be broken down into two main categories. The first category includes recognition, rescue, and first aid that is administered at the dive or accident site. The

second phase of the treatment is the specific treatment that is administered at a medical facility that has hyperbaric capabilities.

Recognition of Decompression Sickness

Signs and symptoms of decompression sickness depend upon location and size of the nitrogen bubbles. The rate of onset of the symptoms is largely dependent upon the type of tissue in which the nitrogen bubbles have formed. Symptoms involving the central nervous system (the brain or spine) will generally be more apparent than those involving tissues like cartilage and fat.

Symptoms usually appear within a short period of time following a dive. Fifty percent of all cases show symptoms within 1 hour after the dive and 95% of all cases have demonstrated symptoms within 3 hours. Remaining cases generally show symptoms within 6 hours. If more than 24 hours have elapsed following a dive, the problem is not likely to be decompression sickness. There are, however, some very rare cases where the symptoms have taken more than 24 hours to manifest themselves.

Signs and Symptoms

The classical and most common symptoms of decompression sickness are joint and limb pain. Shoulders are most commonly affected, and pain may also appear in elbows, wrists, hips, knees, and ankles. Pain most commonly occurs in the upper body. Initially the affected area may feel numb. As time increases, the pain usually becomes more intense and is commonly referred to as "deep and throbbing". Movement of either the limb or joint usually aggravates the pain and often a bent position provides maximum amount of comfort. It is because of this more comfortable bent position that decompression sickness has become known as the "bends".

Central nervous system (CNS) disorders may also be present. In the case of a CNS hit, symptoms may include blurred vision, vertigo, hearing and speech difficulty, nausea and vomiting, weakness, numbness, headache, confusion, lack of balance, backache, and loss of consciousness. These symptoms may be associated with a number of other diving and non-diving maladies. Any time that decompression sickness is suspected, however, it is important to begin the first aid and treatment immediately.

Another area where bubbles may form is in the veins or blood stream. A condition known as the "chokes" occurs when the bubbles formed in the veins are trapped in the lungs. These bubbles obstruct blood flow through the lungs which may cause shortness of breath, chest pain, and coughing.

There have been cases reported where symptoms have also included skin rash and itching. These symptoms usually occur following deep, short dives and are caused by bubbles blocking the capillaries just under the surface of the skin.

There are a number of symptoms that are common to both decompression sickness and air embolism. It may be difficult to distinguish between the two. However, the on-site first aid for these two maladies is the same and distinguishing between them may not be critical. Most importantly, begin first aid immediately.

First Aid For Decompression Sickness

First aid for decompression sickness may be summed up in four main steps. Each of these are important during the on-site administration of first aid.

1. Victim Position

Place the Victim in a Supine Position *(lying the victim on their back)*. Recommendations from the Workshop on Diving Accident Management as reported in *Pressure*, Vol. 19, No. 2, March/April 1990 state:

"It seems prudent to keep the patient in a supine position, but current knowledge does not support the use of the head down position."

Previously, first aid procedure for the body position of a victim with decompression sickness was the modified Trendelenburg position.

The supine position serves several purposes. Primarily, it helps maintain blood flow to critical organs even though arteries to these organs may be partially blocked by bubbles. In the past it was believed that the head down position *(Trendelenburg position)* helped bubbles flow towards the feet preventing damage to critical organs, however, this belief has no physiological basis. A secondary benefit of the supine position is that it helps in the treatment of shock.

2. Maintain Life

Maintain Life is a collective step that monitors several critical areas. We refer to this step as maintaining the body's vital functions.

First, monitor **Breathing**. Open the airway and check for

breathing. Watch the chest for movement and listen and feel with your ear near the victim's mouth. If there is no breathing begin administering artificial respiration.

Second, monitor **Circulation**. An absence of breathing may also indicate that there is no heartbeat. Check the pulse at the carotid artery for 10 to 15 seconds. If there is no heartbeat, then administer cardiopulmonary resuscitation (CPR).

Third, check for **Bleeding**. There is no more serious life threatening situation than severe arterial bleeding. First aid for bleeding may include direct pressure, elevation of wounded area, use of pressure points, or any combination of these techniques.

Forth, the final item under this procedure might be the consideration of **Poisoning** from some aquatic life.

After the four areas of **Maintain Life** have been checked, verified, and dealt with, it is time to continue with the third phase of the first aid.

3. Administer Oxygen

Immediate administration of oxygen has been demonstrated to be most beneficial to victims of both decompression sickness and lung over-expansion problems. Oxygen should always be administered in as high a concentration as possible *(preferably with a demand oxygen system)*.

4. Treat For Shock

The final phase of first aid is to treat for shock. Shock has been responsible for people dying from what should have been a non-fatal injury. The treatment for shock includes raising the legs and maintaining normal body temperature.

Evacuation to a Medical Facility

Following immediate administration of proper first aid it is important to evacuate the victim to a medical facility that has a hyperbaric chamber. During transportation, it is important to continue administering oxygen.

Medical Treatment / Hyperbaric Chamber Therapy

The current treatment for decompression sickness is oxygen alternated with air recompression. In most cases of decompression sickness this entails a treatment depth of 60 feet while alternating the administration of oxygen and air. Note, however, that for air embolism and severe cases of decompression sickness the diver may be recompressed to a pressure depth of 165 feet of sea water while breathing air followed by a return to 60 feet with alternating administration of oxygen and air.

Classes of Decompression Sickness and Hyperbaric Treatment

Type I Bends

Type I Decompression Sickness (DCS) is associated with "pain only" or "skin rash" bends. These milder (yet extremely painful in many cases) types of decompression sickness do not display any neurological or pulmonary symptoms. The typical treatment is prescribed by Table 5 of the U.S. Navy Dive Tables. This relatively minor treatment is only 135 minutes in length, and may be used for Type I bends if the patient gets complete relief of all symptoms within 10 minutes of breathing oxygen at 60 feet. If pain is not eradicated within the prescribed 10 minutes, Treatment Table 6 should be implemented.

Type II Bends

Table 6 is for "serious symptoms" which are referred to as Type II bends and consist of neurological or pulmonary symptoms. As was previously stated, this table is also used for Type I or "pain only" cases that did not respond with complete relief to treatment with oxygen at 60 feet for 10 minutes. Table 6 is also used as treatment for reoccurrences of previously treated decompression sickness. This table is 285 minutes in length *(and may be lengthened by 100 minute increments if required)* and alternates the administration of oxygen and air.

For additional information, treatment for air embolism is as follows. Table 5A is used for cases of air embolism that show complete resolution of all symptoms within 15 minutes of breathing air at 165 feet. If symptoms are still present at 15 minutes, Table 6A is used. This provides for a maximum of 30 minutes at 165 feet. Generally speaking, the benefit of recompression to 165 feet is realized within minutes of achieving that depth. Following the exposure to 165 feet, decompression to 60 feet occurs and the alternating administration of oxygen and air are started.

It has been found useful for patients that have persistent neurological symptoms following the proper initial treatment based on the tables to re-treat them with pure oxygen at a pressure of 2.5 atmospheres for 90 minutes once or twice a day for several days.

The Test of Pressure

In cases where there is a question as to whether or not a patient actually has decompression sickness, there is an option of undergoing a Test of Pressure. This test involves recompression in a chamber to a depth of 60 feet for twenty minutes while breathing oxygen. If the pain is unchanged in intensity, nature, position, or quality, it is usually safe to assume it is not decompression sickness. If the pain is eradicated, an assumption is made that the test is positive and treatment for decompression sickness is continued.

Glossary of Dive Computer Terms

A

AAUS American Academy of Underwater Sciences:

A national organization comprised of scientists from university level educational institutions that conduct an active academic diving program for scientific studies. This organization creates standards for diving within the scientific community and can be reached at:

947 Newhall St.
Costa Mesa, CA 92627

Absolute Pressure:

The terminology used when the earth's atmospheric pressure is part of a pressure measurement, thus the measurement is all inclusive or absolute. Example. An additional amount of 14.7 psi (atmospheric pressure) is added to the water pressure to provide an absolute pressure measurement

Activation:

The operational starting of an instrument to begin its designed functions.

Air Time:

The amount of time available to a diver before a set ending pressure is reached. The calculations are based on the diver's current air supply breathing rate and depth. A calculation of available breathing air for a diver at a specific depth and breathing rate relative to time until a set ending point. This set point can be an empty tank, 500 psig in a tank, the surface, or any other arbitrary ending point.

Algorithm:

A process for solving a mathematical problem which requires the frequent repetition of a series of specific components of a mathematical formula. Many dive computers are referred to by the differences in their decompression model's algorithm which is another way of saying the program is different.

Allowable Nitrogen Loading: (See M-Value)

Ambient Pressure:

Pressure exerted by the surrounding environment at a particular point of reference. Whether it be air at sea level (atmospheric pressure) or sea water at 30 feet of depth, the term refers to the total pressure at the point of reference.

Analog Display:

A representation of data presented continuously along a scale. Most analog displays show their data in the form of a circular face (e.g. the display face on a bourdon tube based submersible pressure gauge).

Ascent Rate:

The speed of vertical movement towards the water's surface.

Atmospheric Pressure:

Pressure resulting from the earth's gaseous atmosphere. A standard atmosphere is defined as 14.7 pounds per square foot of pressure.

B

Bends:

One of the common names used to describe Decompression Sickness (DCS). The name refers specifically to the bent over posturing of people afflicted by DCS.

Glossary of Dive Computer Terms

Buhlmann Decompression Model:
Decompression model developed by Dr. A.A. Buhlmann at the University of Switzerland. Starting in the 1950's, Dr. Buhlmann has worked continuously to modify this model based on experimental data.

Buhlmann Tables:
The tables calculated from the Buhlmann Model.

C

Ceiling:
The minimum depth a diver can ascend to without violating the decompression model. Some dive computers use this moving depth as their minimum decompression stop.

Compartment Half Times:
The speed with which a compartment "on" or "off" gases is measured by the half time. This half time is considered the time it takes a Compartment to transfer half of its excess gas as the result of a pressure gradient between initial compartment pressure and the ambient pressure.

Compartments:
A theoretical representation of a tissue selected from within the model. Decompression Models can be composed of a variety of Tissue Compartments that offer a wide range of Half Times.

Compartment Saturation:
That theoretical point in a Decompressions Model where the Compartment's nitrogen pressure is equivalent to the ambient nitrogen pressure. According to some Decompression Models, once saturation has been achieved for a specific tissue compartment, no more loading of nitrogen can occur at that depth.

Console:
An instrument package that contains two or more instruments used to monitor depth, bottom time, surface intervals, air pressure and/or decompression status.

D

DAN Divers Alert Network:
A non profit organization that disseminates information to the diving public and offers telephone assistance for locating treatment facilities that can provide medical care for barotrauma injuries. For more information this organization can be reached at:
P.O. Box 3823
Duke University Medical Center
Durham, NC 27710

Data Recall:
A dive computer's ability to store data points of information measured during a dive and the downloading of this data at a later time. This transfer of information is through an interface system specific to the dive computer.

DCS Decompression Sickness:
A malady caused by bubble formation in the body resulting from rapid reduction in ambient pressure.

DCS Type 1:
Decompression Sickness Type I: A category of Decompression Sickness that manifests itself in the form of pain in the arms, legs, and shoulders, muscular weakness, skin changes; strange sensations, and some cases numbness in certain areas.

DCS Type 2:
Decompression Sickness Type II: Serious Decompression Sickness that manifests itself in the form of severe paralysis, unconsciousness, shortness of breath, numbness, and substantial impairment of the central nervous systems functions. This type of classification can result in permanent neurological damage.

Deactivation:
The point at which a dive computer stops running its normal dive profile sequencing and data collecting. Deactivation can occur after the dive computer model is desaturated, as a resting stage while waiting for the first dive, or by manually shutting the down in some dive computers.

Decompression:
The act of providing an opportunity for excess nitrogen gas in the body to be removed. Decompression stops along with controlled ascents provide the time / pressure control to allow an acceptable rate of nitrogen transfer out of the body or out-gassing thus avoiding Decompression Sickness (DCS).

Decompression Dive:
A dive in which the no-decompression limits are exceeded. This would not allow a direct ascent to the surface due to the level of absorbed nitrogen gas in the body.

Decompression Stop:
A depth in a Dive Profile at which the diver must stop ascending and wait until an adequate amount of nitrogen is off-gassed to allow continuation to a shallower point along the planned ascent route. Decompression stops usually consist of a set depth and time at which the Diver must remain until the Dive Plan call for continuation of the ascent.

Desaturation Time:
The amount of time for all residual nitrogen to be eliminated from the model following the dive.

Differential Pressure:
Driving force for gas up-take or elimination. Difference in pressure between Compartment and Ambient Pressure.

Digital Display:
The presentation of data where values are represented in numerical digits. Unlike the Analog Display, Digital displays do not provide continuous information along a range. They display discrete values within a range.

Dive Computer:
A microprocessor based electronic instrument that provides data based upon a specific decompression model.

Dive Log:
The terminology used to describe the retrieval of information or data from a previous dive or series of dives to form a record of that activity.

Dive Profile:
The depth / time history of a dive. Most Dive Profiles consist of Bottom Time, Maximum Depth, and Surface Interval. Some dive computers can record numerous parameters of a dive profile, and in some cases, with great detail.

Dive Tables:
A tabular representation of a decompression model in the form of a chart or series of charts. These charts or tables comprise a series of depths and times in relation to each other based on the Decompression Model.

Dive Time:
This term refers to the total immersion time underwater. Most dive computers commence and stop the timing of immersion at a depth just below the water's surface.

Doppler Bubble Detector:
A device that uses the Doppler Effect to monitor specific areas of the circulatory system and detect the presence of bubbles as measure of decompression stress.

Doppler Effect:
Named after an Austrian physicist, this concept is based upon the changes in reflected, or emitted, wave frequency's from a moving object.

Dot Matrix LCD:
A Liquid Crystal Display which uses a series of dots or squares to create the images on the face of the display.

E

E-E Model (Exponential-Exponential Model):
A model which states inert gas absorption and elimination from a compartment occurs in an exponential manner.

E-L Model (Exponential-Linear Model):
A model which states inert gas absorption occurs in an exponential manner while elimination occurs in a linear manner.

Equilibrium:
A balance of state between two forces or actions where dynamic action between the two has stopped or is in a static condition. The term is often used by diving physiologists when referring to the divers' body reaching a natural state with its surrounding environment.

F

FFW:
Feet of fresh water

FSW:
Feet of sea water

Fast Tissues:
Those theoretical tissue compartments that are defined by the Decompression Model as having an on and off gassing rate that is relatively fast and with small half times. These tissues tend to control deep dives.

G

Graphic Display:
A non-numeric presentation of data that presents the data in pictorial form and in a manner relative to one another. Bar, pie, line, and triangle (stacked graphs) are just a few examples of how information is displayed graphically.

Glossary of Dive Computer Terms

H

Hahn Decompression Models:
Modifications of the Buhlmann model developed by Dr. Max Hahn to be used in various dive computers.

Haldane Decompression Model:
Model developed by J. S. Haldane in the early 1900's which formed the foundation for most of the decompression models and tables that have been developed.

Half Time:
See Compartment Half Time.

Hang Time:
The slang term used to indicate a decompression stop point in a dive profile where the diver cannot continue to the surface and must wait for the excess gasses in the body to escape.

High Altitude Diving:
Any diving that is technically above sea level. Many dive computers do not consider a dive as High Altitude unless used at 2,000 or more feet above sea level.

Hit:
The slang term used to describe the occurrence of Decompression Sickness. Other terms referring to DCS would be the "Bends", "Caissons Disease", or the "Chokes".

Huggins Decompression Model:
Haldanean model based on Spencer's No-Decompression Limits. See Spencer No-Decompression Limits.

Hyperbaric Chamber:
A chamber in which the internal pressure can be elevated by introduction of compressed air (or other gasses). Used primarily for medical treatment, physiological studies, and commercial diving operations.

I

In Gassing:
A term used to reference the absorption or transfer of gases (generally those breathed) into the tissues and fluids of the body.

Initialization:
The term used in dive computers to indicate that the unit has sensed and zeroed its depth time functions to commence operations and a dive. This sequence is part of the activation process.

L

LCD Liquid Crystal Display:
The standard electronic component in dive computer that displays information to the diver. The characters on the screen are created by electrical stimulation of segments and the ensuing patterns they form. These patterns provide numbers, letters, graphs, etc.

LCD Segment:
That part of a Liquid Crystal Display (LCD) which creates the parts of characters. These characters in turn can represent numbers, letters, graphs, etc.

LED Light Emitting Diode:

An electronic component called a semiconductor diode that radiates light when a specified current flows through it. Many are designed to give off red or amber light and are used as warning indicators in some dive computers.

M

M-Value:

The maximum amount of nitrogen (or other inert gas) allowed in a compartment at a specific depth. M_0 refers to allowable pressure at the surface. M_{10} is the pressure allowed at 10 feet of sea water. In practical diving terminology this represents a theoretical point in a dive computer's decompression model during an actual dive where the maximum bottom time is reached and any further continuation of the dive at that particular depth or deeper will require decompression stops or a ceiling. Each Decompression Model's Tissue Compartments are assigned their own M-values.

Microprocessor:

The component inside a dive computer that performs the calculations. It is usually a large scale integrated circuit.

Multi Day Diving:

A series of dives performed over consecutive days. Most prevalent from liveaboard dive boats or dive resorts where there are continuous opportunities to dive.

Multi Level Computer Diving:

A style of diving using the advantages of a dive computer to allow more precise Decompression Theory calculations, thus the ability to more accurately traverse wide depth ranges during the time of a dive. This style of diving is possible with the computer where as previous technology required the dive profile to be strictly a "Square Dive" style. See "Multi-Level Diving".

Multi Level Diving:

The type of diving where dive profiles indicate a series of varied depths during the dive's bottom time. If plotted as Depth vs. Time, the graph would show a series of depth changes during the dive time. The use of computers allows this type of diving versus the older "Square Profile" style. "Square Profile" diving requires the deepest point in the dive at the start of the dive time and then a smooth rise over time towards the surface as the dive time continues. The Multi-Level style of diving requires a computer or special tables, and is vary popular in tropical regions where reef walls provide a variety of subjects in a wide vertical range.

N

NEDU U.S. Navy Experimental Diving Unit:

A part of the U.S. Navy that plays an important role in the development of new technology and techniques for use by the operational and special forces of the U.S. Navy.

Nitrogen:

A colorless odorless gas that makes up approximately 79% of the air in the earth's atmosphere. It is physiologically an inert gas which is responsible for both Nitrogen Narcosis and Decompression Sickness.

Nitrogen Loading:

A term used to reflect the amount of nitrogen diffused into a tissue compartment after a specific time and depth.

No Decompression Dives:

Diving where the dive profile creates a small enough tissue compartment loading to allow the diver to make a direct ascent to the surface at the end of the dive.

No-Decompression Limits:

The maximum combination of depth and Dive Time allowed before the dive profile creates a Decompression Dive.

O

Out Gassing:

A term used to reference the diffusion or transfer of gases (generally those breathed) out of the tissues and fluids of the body.

Oxygen:

A colorless odorless gas that makes up approximately 21% of the air in the earth's atmosphere. Oxygen is a vital part of the human body's physiological process.

P

Pressure Transducer:

An electronic device which converts the force of pressure into an electronic signal. In dive computers, this component provides the interface to the environment's pressure. The computer can interpret signals from the pressure transducer and produce a numerical depth on the LCD. Dive computers use low pressure transducers to determine depth and high pressure transducers to determine tank pressures.

R

RAM Random Access Memory:

The memory system of a computer in which any memory data point can be accessed as easily as any other, and the data arrives at the output at almost the same time. A large amount of RAM in a computer allows for faster and more complex calculations of input and output of data.

Repetitive Diving:

Diving profiles that are performed while the decompression model indicates Residual Nitrogen.

Reverse Dive Profiles:

Dive profiles that violate the concept of progressively diving at shallower depths.

RNDT Remaining No Decompression Time:

The term used by some dive computers to indicate the time which remains at the present depth before a theoretical M_0-Value is reached and decompression stops or a ceiling will occur. The result is that an immediate ascent to the surface will not be allowed if your RNDT drops below zero.

RNT Residual Nitrogen Time:

That amount of nitrogen remaining in the decompression model following a dive.

Rogers Model:

Model developed by Ray Rogers D.D.S. based on Spencer No-Decompression Limits. Used to calculate PADI's Recreational Dive Planner.

ROM Read Only Memory:
The memory system of a computer in which any memory, program or code cannot be accessed for change, only read. The ROM system can only be read thus the actual input and resultant output data points occur in the RAM part of the computer.

S

SCUBA:
The acronym which stands for Self Contained Underwater Breathing Apparatus.

Safety Stop:
Additional time spent at shallow depths even though the dive computer or Dive Table indicates a direct ascent to the surface is possible. This is the manner in which many divers accommodate their metabolic and physiological differences that may fall outside the parameters set by the Theoretical Decompression model being used.

Scrolling:
A computer term describing the activity on an LCD where data and information is sequentially shown as a series over a period of time. The most common type of scrolling displayed on dive computers is No-Decompression Limits.

Slow Tissues:
Those theoretical tissue compartments that are defined by the Decompression Model as having an "on" and "off" gassing rate that is relatively slow and with large half times. These tissues tend to control the shallow portion of dives and play a significant role in dive profile series that involve numerous repetitive/multi-day dives.

Spencer No-Decompression Limits:
Revised No-Decompression Limits by Dr. Merrill Spencer based on Doppler Bubble studies.

Square Profile:
The typical dive profile planned when using Decompression Tables. Unlike the multi-level profile the square profile generally consists of a direct descent to a maximum depth, a continued excursion at that depth, and then a direct ascent to the surface.

Supersaturation:
Occurs when nitrogen pressure in a compartment exceeds ambient pressure. At this point a driving force for bubble formation exists. Most decompression models assume that a certain level of supersaturation can be tolerated as representative by the M-Values.

Surface Interval:
Most dive computers calculate this as the time from the moment the diver reaches the surface to the point at which the diver commences another dive. Each type of dive computer will vary a few of feet on their starting and stopping point of a surface interval.

T

Table Based Diving:
The use of a table(s) to estimate the amount of acceptable Bottom Times and Surface Intervals when diving a series of Dive Profiles. These tables may take the form of circular, square, or rectangular design with all having the intent of providing a simple and traceable path to follow when used. Table Base Diving is generally restricted to Square Profile dives and do not allow the ease or latitude for dive planning of Multi-Level type dives compared with dive computers.

Time To Fly:
An indication by a dive computer of the amount of time based on its model, until it is considered acceptable to the fly on a commercially pressurized aircraft. This time is not acceptable for non-pressurized aircraft.

Tissue Compartments: (See Compartments)

Tissue Compartment Half Times: (See Compartment Half Times)

Tissue Saturation: (see Compartment Saturation)

U

U.S. Navy Repetitive Dive Tables:
The most widely used or copied set of tables and data used for the calculating of RNT when divers perform repetitive dives. These tables are Haldanean based and have been in use for over thirty years.

U.S. Navy Standard Air Decompression Tables:
The most widely used or copied set of tables and data used for the calculating of Decompression and No-Decompression dives. These tables have been in use for over forty years and are still the most commonly taught tables in the certification of scuba divers.

U.S. Navy Extreme Exposure Tables:
Decompression Tables developed by the U.S. Navy that are designed for Dive Profiles which are very deep (in excess of 160 FSW), or are very long, and will require extreme periods of Decompression. Generally considered to be "High Risk"

UHMS The Undersea and Hyperbaric Medical Society:
An organization comprised primarily of Medical Physicians and Hyperbaric Physiologists whose interests lies in hyperbaric physiology and medicine. This organization can be reached at:
9650 Rockville Pike
Bethesda, MD 20814

Ultrasonic Doppler Studies:
The use of the Doppler Effect to study bubble formation and movement in the body (specifically the circulatory or blood system) as a measure of decompression stress.

Bibliography

Balldin, U. I., "Venous Gas Bubbles while Flying with Cabin Altitudes of Airliners or General Aviation Aircraft Three Hours After Diving", *Aviat. Space and Environ. Med.*, 1980; v.51.1: 649-652.

"Boycott, A. E., Damant, G. C. C., and Haldane, J. S., "The Prevention of Compressed Air Illness," *Journal of Hygiene*, 1908; v.8.3: 342-443.

Buhlmann, A. A., *Decompression/Decompression Sickness*, Berlin: Springer-Verlag, 1984.

"Edge Users Alert," *In Depth*, April 1990; v.5.4: 10.

Epstein, P. S. and Plesset, M. S., "On the Stability of Gas Bubbles in Liquid-Gas Solutions," J. Chm. Phys., 1950; v.18: 1505-1509.

Garmon, L., "A Bubble is Bubble," *Science News*, September 20, 1980; v.118: 186-188.

Graver, D., "NAUI's New Dive Tables," *Sources*, March/April 1990; v.2.2: 17-18.

Hanauer, E., "Things... About Dive Tables – New Decompression Theory," *Discover Diving*, November/ December 1990; v.8.6: 18-19.

Hempleman, H. V., "Further Basic Facts on Decompression Sickness," *Investigation Into the Decompression Tables, Medical Research Council Report*, UPS 168, London: 1957.

Hennessy, T. R. and Hempleman, H. V., "An Examination of the Critical Released Gas Concept in Decompression Sickness," Proc. Rov. Soc. London B 1977; v.97: 299-313.

Hills, B. A., *Decompression Sickness*, New York: John Wiley and Sons Inc., 1977.

Huggins, K. E., *Microprocessor Applications to Multi-Level Air Decompression Problems*, MICHU-56-87-201, Ann Arbor: Michigan Sea Grant Publications, 1987.

Kunkle, T. D. and Beckman, E. L., "Bubble Dissolution Physics and the Treatment of Decompression Sickness," *Med. Phys.* 1983; v.10: 184-190.

Lang, M. A. and Hamilton, R. W., *Proceedings of the American Academy of Underwater Sciences Dive Computer Workshop*, USCSG-TR-0189, Costa Mesa: University of Southern California Sea Grant Publication, 1989.

Lanphier, E. H., "Sixty Feet Per Minute. Why?," *Sources*, March/April 1990; v.2.2: 33-34.

Lewbel, G. S. and Innis, M. B., "A Critical Look at the U.S. Divers Monitor 2," *In Depth*, February 1990; v.5.2: 9-12.

Lewbel, G. S., "A Review of the Dacor Micro Brain Pro Plus," *In Depth*, March 1990; v.5.3: 9-12.

Lewbel, G. S., "When Dive Computers Push Each Other Around," *In Depth*, December/January 1989/ 90; v.5.1: 11-15.

Lewis, J. E., "A Review of Ascent Procedures for Recreational Divers," *Sources*, March/April 1990; v.2.2: 27-28.

Lewis, J. E., "Dive Computers and The Myth of the 480-Minute Tissue," *Sources*, March/April 1990 v.2.2: 29-31.

Lewis, J. E. and Shreeves, K. W., *The Recreational Diver's Guide to Decompression Theory, Dive Tables and Dive Computers*, Santa Ana: PADI, 1990.

Lippmann, J. M., "Dive Computers," *SPUMS Journal*, 1989; v.19.1: 5-10.

Lippmann, J. M., "Dive Computers and Flying After a Dive to 39 Meters for 10 Minutes," Sources, November/December 1990; v.2.6: 55-56.

Loyst, K., and Steidly, M., *Diving With Dive Computers*, Watersport Publishing, Inc. 1989

Murphy, G., "Beuchat's Aladin Pro: A Decompression Computer for Sport Divers," *Skin Diver*, February 1990: 16-17.

Bibliography

Murphy, G., "Dacor's Micro Brain Pro Plus: A Tiny Computer with a Powerful Brain," *Skin Diver*, July 1990: 64-65.

Murphy, G., "Oceanic's DataMaster Sport: It's More Than Just a Dive Computer," *Skin Diver*, April 1989: 36-37.

Murphy, G., "Orca's MkII: The Biggest Selling Dive Computer in America," *Skin Diver*, January 1990: 20-21.

Murphy, G., "Sea Quest's SME-ML: An Advanced Program for Multi-Level Diving," Skin Diver, May 1990: 22-23.

Murphy, G., "Sherwood's Source: For Simplified Push Button Computer Diving," *Skin Diver*, April 1990: 48-49.

Murphy, G., "Suunto's SME-ML: A Handy Little Multi-Level Dive Computer," *Skin Diver*, October 1989: 36-37.

Murphy, G., "U.S. Divers Monitor: A Broad Range Multi-Level Dive Computer," *Skin Diver*, June 1990: 42-43.

Orca Industries, Inc., Memo - Production Software Changes, June 29, 1990.

Report on 1988 Diving Accidents, Durham: Divers Alert Network, 1989.

Rossi, D., "Dive Computers in High Altitude Diving," *Discover Diving*, November/December 1990; v.8.6: 68-70.

Sheffield, P. J., *Flying After Diving: Proceedings of the Thirty-Ninth Undersea and Hyperbaric Medical Society Workshop*, February 24, 1989, UHMS Publication No. 77 (FLYDIV) 12/1/89.

Sherwood-West, Memo - The Source: Second Generation Improvements, December 3, 1990.

Somers, L. H., *The University of Michigan Diving Manual, Vol. I: Diving Theory*, Ann Arbor: The University of Michigan, 1990.

Strauss, R. H., "Bubble Formation in Gelatin: Implications for Prevention of Decompression Sickness," *Undersea Biomed. Res.*, 1974; v.1: 169-174.

TenBruggencate, J., "UH Panel has new theory in science's war on bends," *Honolulu Advertiser*, March 29, 1980: A-1, 4.

Wienke, B. R., *Basic Decompression Theory and Application*, Los Alamos National Laboratory.

Wienke, B. R., "Bubbles – The New Look," *NDA News*, March/April 1988: 33-34.

Wienke, B. R., "Computational Decompression Models," Int. J. *Bio-Med. Comp.* 1987; v.21: 205-221.

Wienke, B. R., "DECOMP: Computational Package for Nitrogen Transport Modeling. In Tissues," *Comp. Phys. Comm.*, 1986; v.40: 327-336.

Wienke, B. R., "High Altitude Diving – Up and Then Down," *Sources*, November/December 1990; v.2.6: 45-47, 52.

Wienke, B. R., "Limitations to Present Decompression Tables and Meters," *Sources*, May/June 1990; v.2.3: 47-50.

Wienke, B. R., "Multi-Diving Within Bubble Models," *Sources*, September/October 1990: 42-44.

Wienke, B. R., "Multi-Tissue Algorithm and Issues: Part One," *Sources*, November/December 1989: 53-54.

Wienke, B. R., "Multi-Tissue Algorithm and Issues: Part Two," *Sources*, January/February 1990: 54-56.

Wienke, B. R., *Multi-Tissue Decompression Computers and Tables*, Los Alamos National Laboratory.

Wienke, B. R., "Safety Stops and Slow Ascent Rates, part 1" *Sources*, March/April 1990; v.2.2: 47-50.

Wienke, B. R., "Safety Stops and Slow Ascent Rates, part 2" *Sources*, May/June 1990; v.2.3: 57-60.

Wienke, B. R., Tables, Meters, and Decompression Models: Fact and Fancy, Los Alamos National Laboratory.

Wienke, B. R., "Tissue Gas Exchange Models and Decompression Computations: A Review," *Undersea Biomed. Res.*, 1989; v.16: 53-89.

Wong, G., "Flying After Diving," *Sources*, November/December 1990; v.2.6: 51-52.

Workman, R. D., "Calculation of Decompression Schedules for Nitrogen-Oxygen and Helium-Oxygen Dives," *USN Experimental Diving Unit Research Report*, NEDU 6-65, Washington, D.C.: 1965.

Yount, D. E. and Strauss, R. H., "Bubble Formation in Gelatin: A Model for Decompression Sickness," *J. Appl. Phys.*, 1976; v.47: 5081-5089.

Yount, D. E., "Bubble Mechanics: Implications for Safe Ascent," *Sources*, March/April 1990: 24-26.

Yount, D. E. and Hoffman, D. C., "On the Use of a Bubble Formation Model to Calculate Diving Tables," *Aviat. Space Environ. Med.*, 1986; v.57: 149-156.

Manuals:

Dacor Corporation, Dacor Micro Brain Dive Computer Owner's Manual, 0682-63: March 1988.

Dacor Corporation, Dacor Micro-Brain Pro Plus Divecomputer Manual, 0683-28: May 1989.

Oceanic USA, Datamaster II Instruction Manual.

Oceanic USA, Datamaster Sport Instruction Manual Addendum.

Oceanic USA, Datamax Sport Owners Manual.

ORCA Industries, Inc., Dive Computer & Diving Safety, 1989.

ORCA Industries, Inc., Owner's Instruction Manual – SkinnyDipper by ORCA, 1986, 1987.

ORCA Industries, Inc., Owner's Instruction Manual – The Edge Electronic Dive Guide, Revision III: September 1988.

ORCA Industries, Inc., Addendum to The Edge Owners Manual – Edge DIV 6 Software Revision, May 31, 1990.

Parkway/Imperial, Owner's Manual and Instructions for Using the Legend Dive Computer.

Scubapro, Operating Instructions for NC-11 and DC-11.

Sherwood Scuba, The Source Owners Manual.

Suunto, Solution Owner's Instruction Manual.

Suunto, Suunto SME-ML Dive Computer.

Tekna, Inc., Computek Owner's Manual, PN 15693-01: 1990.

U.S. Divers Co., Inc., JM Cousteau Data Scan 2, PN 7410-04: 1987.

U.S. Divers Co., Inc., Owner's Manual and Instructions for Using The Monitor Dive Computer, Edition for Monitor 1, Imperial Version, P.N. 7423-96.

U.S. Divers Co., Inc., Owner's Manual and Instructions for Using The Monitor Dive Computer, Edition for Monitor 2, Imperial Version.

Uwatec AG, Aladin Diving Computer Operating Instructions (Metre), December 1989.

Uwatec AG, Aladin Pro Decompression Computer Operating Instructions (Feet), October 1988.

Uwatec Switzerland, Aladin Pro Information Guide.

Index

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

R

S

Index

T

U

V

W

X

Y

Z

Update Information

As new information is gathered, we will make available updates for a nominal charge. To be notified for these updates, please complete return this form.

Name____

Address____

City__________________________ State__________ Zip____________

Date Book Purchased____________ Purchased from____________________

Dive Computer Presently Own/Plan to Buy ________________________

Please return this form to:

Watersport Publishing Inc.
P.O. Box 83727
San Diego, CA 92138

Please cut page from book

Dive Computers: A Consumer's Guide To History, Theory, and Performance is specifically designed for any diver that either owns a dive computer or is considering purchasing one. **Dive Computers** is a diver's guide to using dive computers safely and to making an intelligent decision as to which dive computer would best fit your diving needs. Get the straight facts about dive computers currently available. Information includes history of dive computers, historical references of the pioneers in decompression theory, explanations of decompression theory and multi-level diving, and a systematic computer comparison and performance section with 24 dive computers.

For those of us who love the underwater world, the advent of dive computers has greatly enhanced our recreation. Using computer assisted multi-level diving techniques will allow more time underwater. Dive computers are tools that must be understood and used properly. Take the time to comprehend decompression and dive computer theory so that you may better interpret their strengths and limitations, and, in turn, realize increased diving safety.

About the authors:

Ken Loyst

Ken is the Publisher/Editor of ***Discover Diving*** magazine, an international diving publication. He is co-author of ***Diving With Dive Computers***, the first publication on dive computers, and author of numerous comparison articles on these electronic devices. A diving instructor and instructor trainer since 1972, Ken stays active testing dive equipment and diving as a professional underwater photographer.

Karl E. Huggins, M.S. Bioengineering

Karl was a co-developer of the EDGE dive computer, which was the first successful microprocessor based dive computer in the U.S. He is presently an Associate Researcher, Diving Instructor, and member of the Diving Control Board for the University of Michigan. Karl is a member of the DAN Advisory Board for Sport Diving Decompression, the American Academy of Underwater Sciences, the Undersea and Hyperbaric Medical Society, and presently holds the position of Decompression Safety Coordinator on the National Association of Search and Rescue's Diving and Water Rescue Committee. He is the 1990 recipient of the Leonard Greenstone Award for Diving Safety.

Michael Steidley

Michael is the Southwest Regional Business Consultant for the National Association of Underwater Instructors. He is also co-author of ***Diving With Dive Computers***, the first publication on dive computers. Michael is an active diving instructor and instructor trainer and underwater photographer.

ISBN 0-922769-09-5

51295

9 780922 769094

Watersport Books
A Division of Watersport Publishing Inc.
P.O. Box 83727
San Diego, California 92138