Welcome to aquaCORPS Digital

In January 1990, I launched the first edition of aquaCORPS magazine because I was hungry for information about a new kind of diving that was emerging from the closet, and no one was talking—there was little or no information. Indeed, deep diving, by which I mean diving beyond 40m/130 ft, and its companion decompression diving—the “D-Words”—were strictly verboten among the recreational diving establishment; few could even spell N-I-T-R-O-X, or trimix, let alone knew what they were.

Within two years I coined the moniker “technical diving,” to distinguish this type of diving from recreational diving, and the name stuck, as technical diving began to gain momentum and spread around the globe. In parallel, the magazine, which we subsequently dubbed aquaCORPS: The Journal for Technical Diving, continued to grow in size and readership.

Each issue of aquaCORPS focused on a single topic such mixed gas technology, rebreathers, decompression illness, computing and more. WIRED magazine described it as, “The Sea Geek’s Bible; Part wish list, part chemistry book, part looking glass.” In addition, we launched aquaCORPS’ sister publication, which was more of a newsletter, titled: technicalDIVER.

In 1996, after growing rapidly and moving to newsstand distribution, I ran out of money and was forced to close the company. By that time, we had produced a total of 12 themed issues of aquaCORPS and three issues of technicalDIVER, along with producing the Enriched Air Nitrox Workshop (1992), four annual tek.Conferences (1993-1996), the first EUROTek and ASIATek conferences (1995), and Rebreather Forum 1 & 2 (1994, 1996).

Now more than 30 years since we launched aquaCORPS, I have begun to release sponsored, digital copies of the original magazine. I want to thank my illustrious, forward-thinking sponsors, all of which are pioneers in their own right, for making this possible. Specifically, I have released, aquaCORPS #4 MIX, #5 BENT, #7 C2 (rebreather), and this issue, aquaCORPS #6 COMPUTING, sponsored by Shearwater Research. In this issue, you will find Shearwater’s sponsored content inserted in the center spread, in what is otherwise, the original magazine.

Over the next few years, I plan to progressively release digital versions of all of the back issues of aquaCORPS/technicalDIVER. These will be distributed by our sponsors and a copy will reside at www.aquaCORPS.online.

Thank you for your interest!

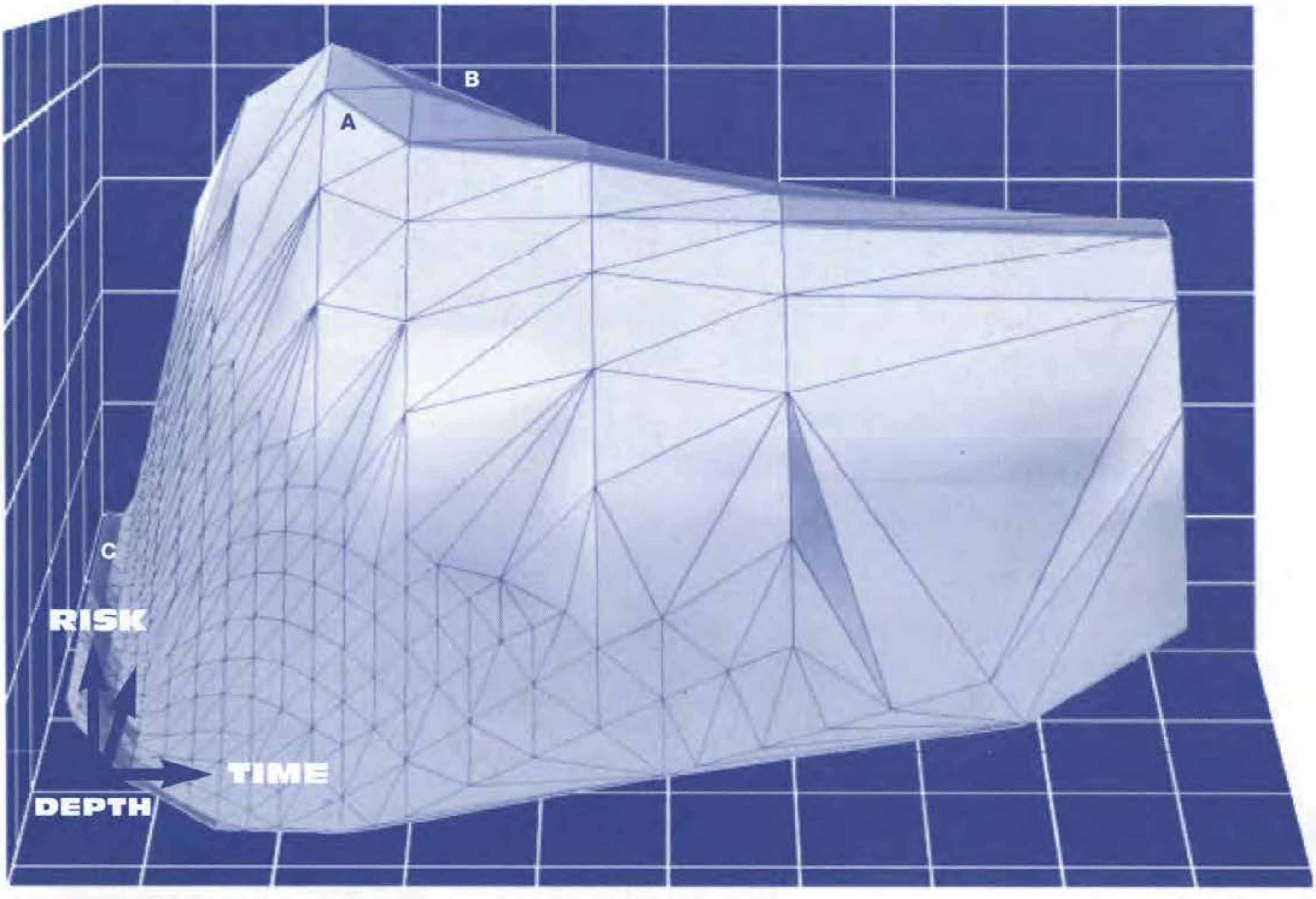
Michael Menduno/M2

THE JOURNAL FOR TECHNICAL DIVING

aquaCorps®

N6

COMPUTING



Late Breaking News...

Oxygen-related incidents appear to be on the rise (see Incident Reports pg. 23). Wolfgang Kanig of Russelsheim, Germany reported another **oxygen-related fatality** when a diver apparently switched to oxygen at 30 msw and convulsed and drowned during a trimix operation to 75 msw (244 fsw) at Lake Bodensee, Germany. Meanwhile **extreme deep air diving**— *the hyperbaric equivalent of Russian Roulette*— still seems to have its enthusiasts. Anchor Scuba, Ft. Lauderdale, FL reported that a diver who wishes to remain anonymous for job security reasons, dove to 469 fsw (144 msw) on air off Ft. Lauderdale and survived— a new world record. Two other "deep air" divers were not so lucky and died (see Incident Reports). Veteran cave diver, Bill Gavin, once compared deep air records to *"setting the Bonneville Salt Flats speed record while drunk—what's the point"* ("For The Record," a/c journal N3, DEEP). If nothing else, perhaps it serves as example of the evolutionary process at work— a matter of *excessive genes*.

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aquaCorps

a message to our members

We've come a long way together since the introduction of our first journal *UnderPressure* in JAN90, yet in many respects the 'self-contained' diving revolution is just beginning. In five to ten years time we will likely look back and wonder how we were ever able to manage at all, and the idea of a 'high tech' diver muscling down a quad or more of cylinders to conduct a dive—*akin to computing with the first 512k RAM 8 bit PCs*—will seem like a primitive notion indeed. Take another breath.

Beginning with this volume of the journal, we are implementing a several changes designed to provide you with more information in a timely fashion and to hopefully insure that a/c will be 'talking the talk' well into the 21st century.

First of all, we are consolidating our *technicalDIVER* publication into a *quarterly* ***aquaCorps Journal*** which will allow us to improve our production schedule further. That means you will receive four information-packed issues of the journal along with the annual tek.GUIDE directory with your annual membership fee. As you can see we are also continuing to add color to the publication.

In addition, we will be expanding our information services to include the annual **tek Conference**, videos, future reports and publications, and eventually, perhaps even software. Watch this space.

If you missed last years **tek.93** conference, don't panic. Short of computing the 'question to the ultimate answer' on your tek decoder ring (*D-rings?*) you can find out what happened at the conference electronically. For an insiders view of the ' technical revolution' and what it could mean to you and your operation, check out our video, ***Talk tek to me,*** based on over six hours of interviews with industry insiders conducted at **tek.93.** Better yet. Plan to beam down to next years **tek Conference** in New Orleans and conduct some interviews of your own. (;—>).

To become a member, renew, purchase **tek** tickets, the video or simply to update your address use the order form on the inside back cover of this wrapper.

This work would have been possible without the interest and commitment of our members. Thank you for your continued support. More to come.

Sincerely,

Michael Menduno
editor & publisher

THE JOURNAL FOR TECHNICAL DIVING

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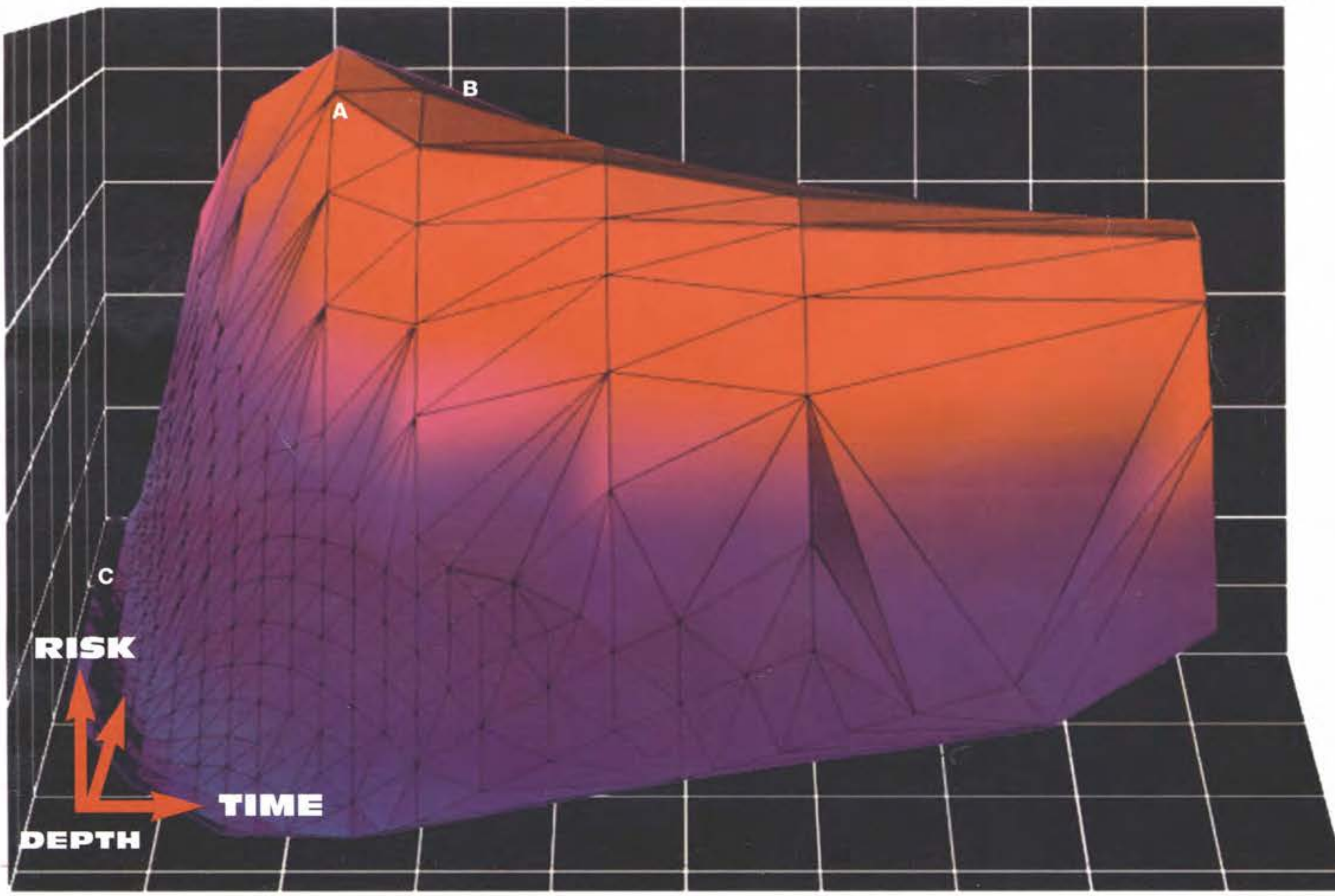

Decompression risk surface showing the risk of DCI for a given depth and time combination according to the USN Exceptional Exposure Air Tables.

"I speak of none other than the computer that is to come after me," intoned Deep Thought, his voice regaining its accustomed declamatory tones. "A computer whose merest operational parameters I am not worthy to calculate— and yet I will design it for you. A computer that can calculate the Question to the Ultimate Answer, a computer of such infinite and subtle complexity that organic life itself shall form part of its operational matrix. And you yourselves shall take on new forms and go down into the computer to navigate its ten-million year program! Yes! I shall design this computer for you. And I shall name it also unto you. And it shall be called....the Earth."

Douglas Adams, The Hitchhikers Guide to The Galaxy

tek INSIDE Fold-out Conference Poster

Desktop Decompression
Nitrox Computing
Extended Range Guidelines
Mix Watch

aquaCorps N6

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ABOUT THE COVER: This image was created by David Story using IRIS Explorer 2.0 on a Silicon Graphics Workstation. Story page 7.

computing

"Yes! I shall design this computer for you. And I shall name it also unto you. And it shall be called....the Earth."

Douglas Adams,
The Hitchhikers Guide to The Galaxy

The introduction of the EDGE dive computer in 1983 launched a revolution that has been a driving force in the industry ever since. By providing realtime computational ability, the DC made decompression diving accessible to a wide range of users and was quickly adopted by the high end of the market. Yet ten years later, with market penetration approaching 25% and annual sales of some 40-50,000 units the computer revolution is only now beginning.

Underscoring the cardinal rule of computing, *"hardware is driven by software,"* the current generation of dive computers is *software-limited* to air diving and as a result has failed to keep with a growing spectrum of in-water applications. Today, air-based DCs offer minimum value in most technical mix applications and have been relegated instead to depth and time keeping duties. Though the extension to "nitrox diving" seems promising and is sorely needed if EAN is to grow, the inability to account for gas switches, minimally to incorporate oxygen decompression, remains a limiting factor.

Not surprising the hot bed of dive computing today is in software. Desktop decompression programs promise to put the power to calculate an application-specific decompression schedule in the hands of individual users—*the power to be your best*— and have commercial application as well. Meanwhile, the increased use of oxygen has generated significant interest in CNS tolerance algorithms and the need for improved dive logging software—*more data*— while on the closed circuit (C^2) front, innovations in microprocessor-based control systems and heads up display technology are the rage. Developments are also under way in underwater imaging and mapping tools and the prospect of "digital" navigation promises a new fix to the problem of diver positioning. These developments and others that will likely follow represent the building blocks of what is to come.

Taking a lesson from the computer industry, the next generation of dive computers will likely be based on a 'standardized' diver-carried hardware platform capable of supporting a variety of software. In fact programmable systems are here in prototype form today. These machines will offer users a range of functionality depending on the software modules selected including; variable mix decompression with selectable algorithms, gas and thermal sensing, user-definable gas management routines, data acquisition, logging and basic diver positioning and navigation. These next generation systems will likely incorporate a simple heads-up user interface display as well.

Further advances in underwater computing such as acoustically-based imaging systems and virtual user interfaces will have to await advances in chip technology along with further developments in virtual reality software. *"Computer? Switching now."* Given the continuing exponential trend in processing power and VR we may not have to wait for long. By the turn of the century we are likely to see virtual imaging systems complete with a dataglove interface incorporated into relatively "low cost" one atmosphere diving suits—*micronewts* anyone? After that it is only a matter of time (and volume) before this kind of capability will become available to 21st century 'sport' divers and professionals or rather, what they will have become.

That's what this issue of aquaCorps is all about. M^2

"I'm very pleased to live at the tail end of a generation that's the first to go into space and to look back at our world and say, Hey, we call it Earth. Why do we call it Earth? We should call it Water because that's what it is."

Phil Nuytten,
"Talk tek to me"
(video)

42
msw
?


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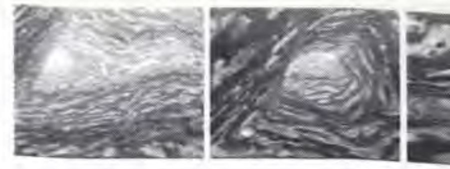


aquaCorps Journal N6 **a/c** Computing 1993

applications & environments:

feature:

risk management:

mix
watch
mix
watch

hardware:

mix watch:

art:

"Decompression tables should be printed on rice paper with disappearing ink." R.W. Bill Hamilton, *37th UHMS Workshop*

MAKING THE VIRTUAL JUMP

by Ian

You're within 5% of your oxygen tolerance at this current work load and PO2," said DAC (Dive Analysis Computer). I glanced out at the display and could see the look-ahead index gradually increasing. The orange warning illumination of the figures lit up, "92 metres and 28 minutes, time to go," I thought. Ambient-pressure diving sure wasn't all that it's cracked up to be but for projects like this it was the only way. I concentrated on getting my orientation right in the ship's gangway. It never ceased to amaze how confusing it can be moving 'up' a gangway that's on its side.

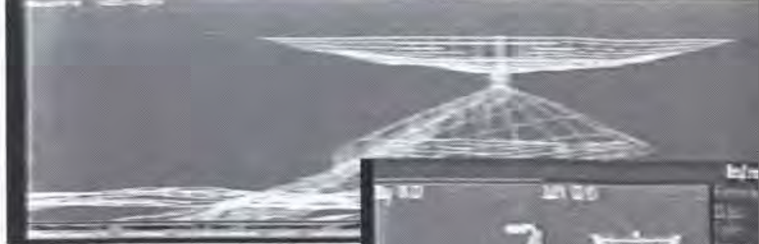
"Ian, I'm on my limit," said Bob," shall we turn for home?" The comms crackled a bit, but then I was used to that from the metal of the wreck. "Which way?", I asked. "I thought you had all the technology," said Bob, "don't tell me the direction circuits are down." "Only kidding, come on this way. Mind the silt, switch to sonar." A seconds pause as the violet lines turned into an actual image. The compass arrow flashed green to show we were on the right route. The buddy arrow showed Bob below me to the right.

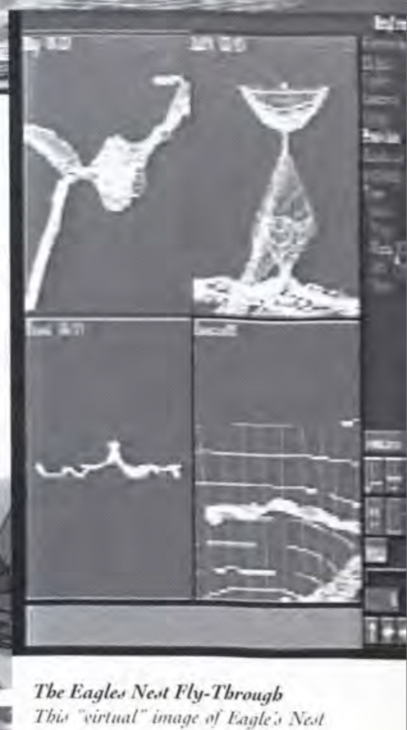
I felt a little cold as we moved to the exit gangway. "Returning to ordinary vision as light levels are acceptable," said DAC. A good job I thought, the virtual imaging always drains the batteries. "Check thermal efficiency," I commanded DAC, an image of a diver popped up in my view outlined in green with a small red section by the knee. "Damn. I thought I'd grazed that gangway a little fiercely." I heard Bob chuckling, "not holed the suit again?" he asked, "Just a nick", I said. So much for 'soft' suits.

I saw the shot line up ahead. The compass arrow started flashing to show we were within 10 feet. "Decom status," I queried DAC. "Ascend to 50 metres for two minutes. You have two minute and 30 seconds to reach the first stop" it replied. "Ascending too quickly, venting suit", droned DAC. "Go to visual," I instructed, just to get away from the sound and save batteries. I should have recharged them before the dive. The buddy arrow showed Bob behind me. I turned, he pointed to his mask with the international broken sign(!) "Have you got audio?" I asked. "Yeah, but my head-up's flashing on and off", he said. Battery problem, I thought. It always did that on the MK1 to show you only had 90 minutes power left at current consumption. "Don't worry, I can link and take us up with my computer."

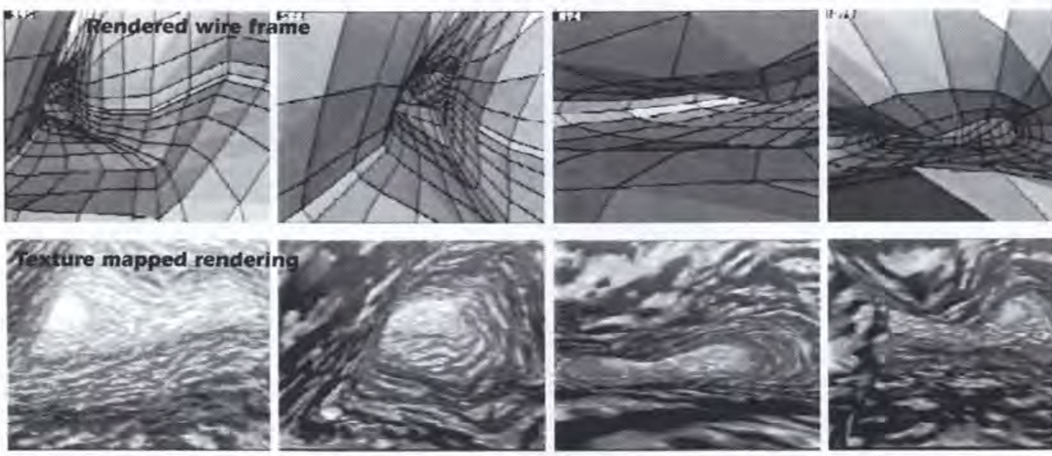
The 50 metre mark flashed and I gripped the shot line. "Switch to nitrox and turn up the heat." I laughed to myself. They must change the software on the next version of the DAC's. Mind you, we should be grateful that the fire departments worldwide made this system possible in the first place. "Ascend to 47 metres", said DAC "for 2 minutes. You have 20 seconds to reach the stop. All systems functioning correctly." The hours ticked slowly while we reviewed the dive on video playback. The boat indicator showed our support vessel right above us. "Ascend to surface." We arrived together. "Now for a nice cup of tea," said Bob. "That's one thing computers can't do for you!"

A simple science fiction story or an insight into the future? Judging from trends in computing, it is a description of what a technical dive could be like in just ten year's time given the significant increases in microprocessing power that are becoming available. This trend will continue through the turn of the century. For the diver, it means that DCs will like-

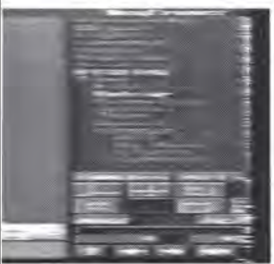




The Eagles Nest Fly-Through
This "virtual" image of Eagle's Nest cave system was developed using an Autodesk CAD file of the system created by Deep Breathing Systems, Sevierville, TN. The database of 3D DXF meshes was loaded into Autodesk's 3D Studio software package running on a 486 PC. The meshes were simplified and given texture details with appropriate colouring. This new database was then converted using a Virtual 'S' Translator Tool to run on a Division VR computer. This enables a "virtual" diver to "enter" the cave system and dive/fly through the 3-D world in real time using a data helmet and glove giving the illusion of being there. A VCR was then used to record the sequence in 2D and the image was "grabbed" using Adobe Photoshop running on a Quadra-level Mac.
(See Mapping Eagle's Nest, p. 45)



Note that the Virtual S system will be a featured exhibit at next years "tek Conference," January 9-11th, New Orleans, LA, enabling participants to make a "virtual" fly-through in the Eagle's Nest system.



ly have far more capability in the future and be able to drive more data input devices such as gas contents, oxygen and CO2 monitoring, positioning and, eventually, imaging systems. These imaging systems will be available as a result of the increased computing power and "virtual reality."

Virtual reality is a tool enabling a user to understand and interact with complex information environments in real time through the integration of computing, imaging and audio technologies. This is accomplished by "immersing" the user in the data environment through the use of human friendly interfaces such as data helmets, gloves and other devices. Today this technology is being applied to a wide range of applications, for example, to aid fighter pilots in managing increasing complex and sophisticated aircraft and weapons systems. Eventually, it will enable divers to make use of virtual imaging as well.

To suggest the sport diving market will be able to support this technology by itself is unrealistic. As cynics in the entertainment community are fond of saying "State of the art technology means state of the art invoices!" The investment costs for realizing this technology may eventually come as a result of applications such as remotely operated vehicles (ROV's) and hazardous environment work.

Organizations from both these industries are currently examining the potential of VR in our development studio in London. This research and development will likely lead to solutions that technical divers may one day utilize. Not only will these tools assist actual dives but perhaps, equally as important, they may someday be used in diving simulators to facilitate training, and better training makes better divers.

Fanciful thinking? So they thought of the space industry which has brought so much accepted technology into every day life. It is a future worth working toward especially when considering from space you can see what covers two thirds of the planet.

Ian Capon is the founder and Managing Director of Virtual S, a virtual reality studio based in London. Former publisher of Sport Diver magazine, he can be contacted at: Virtual S, The Limes, 123 Mortlake High Street, London SW14 8SN, UK, f: 081.392.2424.

A Tekkies Guide To Cyberspace

by Nick Simicich

When divers aren't getting wet, they're usually talking about it. In the old days, a box of slides and a couple of cold ones at the local dive club seemed to do the trick just fine. Today you're more likely to find a tekkie hunched over a tricked out micro-muscle machine uploading their latest 14,400 baud dive fantasy—not to mention a couple of GIF files. Cyberspace is here.

Internet

Internet is a gateway to the largest user base on the planet stretching through Australia, Japan, Europe, Africa, the Mideast, as well as North and South America, including many high tech companies, universities and U.S. government facilities. Electronic mail (e-mail) access to the Internet is also available through Compuserve and GEnie.

Internet's newsgroup, "rec.scuba," offers a forum for divers of all levels to get together. Recent subjects of

continued on p.8

Visualizing Decompression RISK

by David Story

The US Navy Air Tables have probably been used for more dives than any other table in existence, yet the relative risks of various decompression schedules are often poorly understood. The reasons for this discrepancy are two-fold: there is little data on the risks, and that data is difficult to understand. This brief article attempts to address both of these problems by using three-dimensional (3-D) visualizations of data created with IRIS Explorer 2.0 running on a Silicon Graphics workstation. Put simply, these visualizations make it easy to "see" the estimated risks of the US Navy Tables.

Figure 1 is a 3-D visualization of the total decompression time required for each time and depth combination of the US Navy air tables. Bottom times range from 5-480 minutes and depths range from 40-300 fsw (12-91msw). The image on the cover of this issue of the Journal, shows the corresponding estimated risk of decompression illness (DCI) for these dives based on predictive studies by Weathersby et al. Weathersby used statistical modeling methods to estimate decompression risk for each depth/time entry in the US Navy tables. Estimated DCI risks range from a just a few tenths of a percent to over 45%. Colors correspond to values at each point: blue for low time or risk and red for long hangs or high risks.

By presenting data in a three-dimensional format, thousands of numbers can be visualized in one quick glance. Once visualized, the relative trends and some surprising results are easily seen. The decompression time required by the US Navy Tables rises smoothly with increasing depth and time (Figure 1). If you go deeper and stay longer, you must decompress longer. No surprise there. However, the estimated risk of DCI (cover image) rises sharply and appears highest for the intermediate hang times at (A) — but then drops off at (B) as time and depth increase! This apparent anamoly may be due to the data used to calculate risks.

An additional quirk can be seen at (C) on the cover image; the estimated risk actually drops as you pass the no-stop limits! Stated another way, a short-decompression dive is empirically more reliable than a no-stop dive to the table limits. These results reinforce the idea that treating all dives as decompression dives by taking a "safety stop" reduces DCI risk—every dive is a decompression dive.

Three-dimensional visualizations are powerful tools for anyone who has to understand or explain complicated behaviors, such as those found in decompression algorithms.

F1

David Story is the Special Effects manager at Silicon Graphics and has a keen interest in decompression visualization. He can be contacted at: R & D Divers, 1016 East El Camino Real, Suite 501 Sunnyvale, CA 94087, f:415.967.8496.

Weathersby, Survanshi, Hays, and MacCallum, 1986. Statistically Based Decompression Tables III: Comparative Risk Using US Navy, British, and Canadian Standard Air Schedules. Naval Medical Research Institute Report 86-50. See also reports 85-16 and 85-17 for the derivation and verification of the model used to predict these risks.

Getting Connected Online

Internet: Most of the commercial services (Compuserve, GEnie) offer Internet mail access. For full access contact The Well 415.332.4335. **BITNET:** Access BITNET through the Internet. **America Online:** Call 800.827.6364 for a free startup kit. **Compuserve:** Order a membership kit by calling 800.848.8199. Internet e-mail is available. **GEnie:** Set your comm program to half duplex (local echo) 300/1200/2400 8, N, 1 (i.e. 8 databits, no parity, one stop bit) and call 800.638.8369. When you connect, type HHH, and then, at the U#+ prompt, type XTX99048,SCUBA and hit the return key. Follow instructions. Internet mail access is available. **Prodigy:** Prodigy requires a special communication program that can be purchased at many computer stores. **Canadian Diving BBS:** 416.844.6613. **Hyperbaric Safety and Technology Network BBS:** 703.922.0688. **NACD BBS:** Information: 912.246-9349. BBS:912.246.3280 (300-2400 Baud, 8, N,1). **NSS-CDS:** Information: 813.683.1073. Data: 813.684.9400

Cyberspace continued from p.7

discussion ranged from obtaining a copy of Buehlman tables in Amsterdam, using Kodachrome 200 for U/W imaging, to building your own Delphi datareader including decoding the dump format. Internet also offers its own "tekkie" mail list, Techdiver, with about a hundred subscribers. Techdiver discussions have covered a mixed gas decompression program written by one of the subscribers, in-water O2 recompression, and vomiting into your Aga. It isn't unusual to get twenty messages a day.

••••••••••• BITNET

SCUBA-L is a mailing list based on the BITNET network which is connected to the Internet. The audience and topics are similar to those on rec.scuba. SCUBA-L's 300 participant mailing list is maintained at Brown University and a hot topic can generate thirty messages a day. HYPBAR-L is another BITNET list devoted to hyperbaric medicine. Participants are typically hyperbaric technicians or MD's discussing treatment protocols. Five messages per month is the average. The list is based at Technion University in Israel.

••••••••••• Commercial Services

If you cant' get on the Internet, or you just can't get enough, you might consider tapping into a commercial services. Though Prodigy, GEnie, Compuserve, and America Online all have active scuba areas, you'll usually find me on GEnie. One of the advantages of a commercial service is that "sysops" keep the areas organized. Another advantage of the commercial services is that many diving industry vendors are represented as well as quite a few of divings "notables." Have a question for Dive Rite Mfrg., DUI, Ikelite, International Hard Suits, Hamilton Research, ORCA, PADI or aquaCorps, just dial away.

All you need to access GEnie or Compuserve is a modem and terminal emulator program such as Procom or Kermit. There are also navigation programs that will assist you with access, but they aren't required. For Prodigy and America Online, you will need a special access program. Access charges vary, and there may be a monthly fee or an hourly fee, which will depend on the time of day that you call, and what services you use. Typically, there are local access numbers in many areas. Availability varies by service.

••••••• Electronic Bulletin Boards

If you have a special interest, or you are lucky enough to live near an active, regional BBS, you may be no more than a quick phone call away from an information fix. Typically, there is no fee for limited access. Numerous Electronic Bulletin Boards (called BBSs) are run by companies or individuals with an interest in diving. Here are a couple to consider:

The National Association of Cave Divers' BBS is run by John Crea, Submariner Research Ltd. and has 200 registered users with about 30-40 regulars. Typical discussion topics include scooters, decompression, dive site reports, or finding a dive partner. There are 200 registered users with 30-40 regulars. The National Speleological Society's Cave Diving Section (NSS-CDS) has also set up a BBS service that will handle 14.4k baud plus modems (available June93). The Hyperbaric Safety and Technology Network BBS is sponsored by Reimer's Engineering and has about 50 registered users. Most of the on-line discussion revolves around hyperbaric systems and gas mixing. Articles are easily downloaded. Another example of a local, active diver's BBS is the Canadian Diving BBS, in Oakville, Ontario. If I was headed that way and looking for a dive partner, I might well give them a call. See you online.

••••••••••••••••••••••••••••••••

A NAUI, SSI, and HSA instructor, Nick Simicich is a ubiquitous Unix-friendly presence on the net. He can be contacted at: 91 N. Bedford Road, Chappaqua, NY 10514, f: 914.739.5509. GEnie: N.Simicich, Internet: njs%scifi@uunet.uu.net.

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A DIGITAL Approach to Shipwreck and Reef Mapping

by Rod Farb

The U.S.S. Monitor provided the testing ground for a new system of mapping shipwrecks I developed utilizing powerful microcomputers and high resolution video technology. In the fall of 1986, the National Oceanic and Atmospheric Administration (NOAA), the federal agency that manages the Monitor National Marine Sanctuary, determined that my proposal to do photographic research on the U.S.S. Monitor had no adverse impact on the site. This opened the door to testing the new technique I had been working on for more than a year called "computer video image digitization" (CVID). Mapping the Monitor by CVID would provide a baseline from which future studies could determine the rate of deterioration of the site—something that had never before been done. Because of its excessive depth (230 fsw/71 msw) and because no self-contained divers had been permitted to dive on the site since its discovery in 1973, no baseline measurements have ever been made of the wreck. CVID is an ideal tool for mapping deep shipwrecks where bottom time is limited.

CVID involves the marriage of several technologies including high resolution video, digitizing capabilities and powerful computers that, prior to 1988, were available to only the military and the film industry. By 1989, these technologies became available to anyone, but the systems were expensive—$30,000 or more. Undeterred, I contacted computer companies about my idea and within a year IBM, Data Translation, Bioscan, Xerox Imaging, Micrografix, Hewlett Packard, and Agfa Matrix had donated all of the equipment to make it possible to map the U.S.S. Monitor.

In CVID, Hi Band 8mm video and 16mm film cameras are used to acquire images of the wreck. These cameras, filming at a specific orientation to the wreck have a specific measurement standard built into the frame and can capture up to 36,000 images during a twenty minute dive covering every nook and cranny of a site. An IBM Model 80 PS/2 computer equipped with a high resolution digitizing board made possible the acquisition of individual images from the videotape or film. These images could be saved electronically on disks, output on a laser printer or sent to a film recorder for 35mm slides. Using specialized software, objects in the digitized images can then be measured. From these measurements detailed maps of the site can be made.

Both East Carolina University and the Northwest Michigan Maritime Museum are using offsprings of CVID to map specific wrecks. However, CVID mapping is not just limited to shipwrecks. Recently, the PADI Foundation awarded me one of twelve environmental grants to use CVID to map coral reefs in the Caribbean. Changes in reefs, just like shipwrecks, are measurable with CVID.

In the last five years, advances in microcomputers, image capture, digitization and film recorders have made CVID a powerful

PHOTO DENNIS WILLIAMS

Dr. Jill Yager collecting a remiped specimen in Queva de los Carboneros, Cuba using the **YSI 6000 Sonde.** The sonde is a compact environmental monitoring device designed to assess water quality by measuring and recording six fundamental parameters; depth, dissolved oxygen, conductivity, Ph, temperature and oxidation reduction potential (ORP). This data can then be loaded into a PC—
submitted by Robert Spokane.

tool for underwater research. Applications for CVID technology are limitless; mapping a subject is relatively easy provided images can be made.

Author and professional photographer, Rod Farb has worked on assignment for National Geographic and other projects and is well known for his USS Monitor expeditions. He can be contacted at: Rt 1 Box 48AB, Cedar Grove, NC 27231, f: 919.732.6197.

DIVA

The Lady of Commercial Computing

by Jean-Pierre Imbert

Since their introduction in 1983, the dive computer (DC) has become a standard tool for calculating "realtime" decompression in sport and scientific diving replacing the old watch and depth gauge system. However, in spite of their usefulness, DCs have had limited application in commercial diving. This limitation is not the result of a narrow minded attitude towards computing; commercial divers utilize many sophisticated electronic devices including monitoring systems and dive recorders. Rather it is due to the specific operational requirements of the job.

Commercial diving procedures have specific constraints that make their computing requirements quite different then their sport diving counterparts. In fact, self-contained (scuba) diving is not considered to be a professional method of intervention. The inherent freedom of a self-contained diver is viewed as unsafe due to limited gas supplies, the lack of communications and link with the surface in case of emergency. Commercial divers use umbilicals and diving baskets. The umbilical provides and unlimited gas supply, communications, heating, depth monitoring, video camera and a solid link in case of trouble. In commercial diving, everything is directed from the surface.

Illustration by Jean-Pierre Imbert

Although commercial diving is very different from an operational perspective, many people believe that computers, which are common on the job site, could minimize human factor problems and therefore contribute to overall safety. For that reason, Stolt Comex Seaways set up a research programme to define the specifications of a commercial dive computer and develop DIVA. Personal computers with a minimum of a 286 processor and small hard drive were chosen as a platform on their basis of their wide spread availability.

DIVA is a surface-based dive computer designed for use by the diving supervisor. Depending on the parameters established for the dive, it monitors both decompression procedures as well as the overall operation and serves as an onsite "expert system." In countries such as France, decompression tables are published in legislation and are a statutory requirement. In other countries, because of employer liability, the diving company must use well-referenced decompression procedures, such as the US Navy Tables, to demonstrate that they do not expose their employees to any undue risk. In either case, there is little flexibility in selecting the decompression schedules which must belong to official or approved tables. Interpolations and extrapolations are not allowed because each dive must be referenced to a printed document. As a result, realtime decompression calculations are unheard of in commercial diving, rather computing a schedule is a matter of document retrieval. In this regard, DIVA works like a database providing easy access to accepted protocols rather than a realtime calculator.

Commercial diving utilizes documented procedures to cover the span of operations including; air or mixed gas diving, surface supplied or bell diving tables, normal or emergency situations. Dealing with a client may require references to the legislation or guidance from professional associations such as the ADC. DIVA includes a database for reference texts used in commercial diving that are often referred to as the "North Sea Standards," allowing the user to retrieve relevant information by title or by index. The database packs what would be a stack of manuals 1.5 metres high (approximately 5 feet) into three 3.25" disks, saving both rain forest and the supervisors overweight baggage charges. Because these procedural instructions can be quite complex, particularly when it comes to work optimization such as which diving method to use, which bottom time and mix, or how many divers per sift, DIVA has a small built in "expert system" that allows the supervisor to make his choice and define his best job plan.

Finally, DIVA can conduct all the calculations that are expected from an onboard computer. This includes the determination of equivalent depths and other relevant calculations such as mixing and consumption planning for nitrox diving, altitude diving, mud diving or multi-levels diving. It even runs a small data base that stores the onboard gas reserve status and edits gas consumption reports.

Today, a Beta version of DIVA is operating on a test basis at a number of Stolt Comex Seaways job sites and DIVA T-shirts are given out for bug reports.

> *"Can you hear me?"*
> *"Yes," the robot answered promptly.*
> *"Do you recognize me?"*
> *"Yes, Mr. Bradley."*
> *Good, thought Bradley. We're getting somewhere....*
> *"Do you have any problems?"*
> *"No. All systems are normal."*
> *"We have sent a recall—Subprogram 999. Have you received it?"*
> *"No. I have not received it."*
> *"One has been sent out. I repeat: Obey Code 999. Acknowledge."*
> *"I acknowledge."*
> *"Then execute."*
> *"Command not understood."*
> *"Damn."*
> Arthur C. Clark,
> Ghost from The Grand Banks

In the last six months of evaluation we have received very warm comments on the system and have given out a large number of T-shirts as well. Once the system is fully validated and proven reliable, we plan to distribute it throughout our operation sites but are not considering any further commercialization at this time.

Jean-Pierre Imbert is the Quality and Safety Manager at Stolt Comex Seaways and has been involved in a variety of special projects including the development of DIVA and the Comex Hydra Program. He can be contacted at Stolt Comex Seaways, 36 Boul. des Oceans, 13275 Marseille, Cedex 9 France, f: 91.40.12.80

Jim Baden, San Bernadino, CA, preparing for a jump on the *Andrea Doria*. Team Doria Expedition, 1991. *RV Wahoo.*

"In actuality, all maps incorporate assumptions and conventions of the society and the individuals who created them. Only by being aware of subjective omissions and distortions inherent in maps can a user make intelligent sense of the information they contain."

Denis Wood, The Power of Maps, Scientific American, May 1993

One of the great "needs" since the advent of deep self-contained technical diving has been for appropriate decompression tables. Unfortunately, there are no applicable "public domain" tables for most technical divers. Some commercial trimix tables have been tried, but these are not really designed for this type of diving, are not optimized, and are not publicly available.

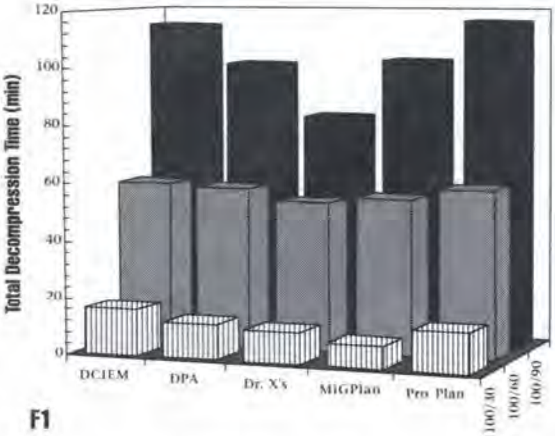
Early technical diving with trimix began with custom tables generated for the specific dive series; many of the early applications were for specific cave diving projects. Custom tables are available from several sources, but they are expensive, especially if a table is used for only one or a few dives. Recognizing this need, several entrepreneurs have recently developed computer programs designed to enable individual technical divers to calculate their own tables. These are moderate in cost, with each of the programs costing about the same as or even less than a single custom table.

This article, the first of a two part series, describes and attempts to evaluate the four currently available programs, which are the Dive Profile Analyzer (DPA)by Cybertronix, Pro Planner by

This review is the first of a two part series evaluating four "desktop decompression" software packages that were recently unveiled at the 1993 tek Conference. Part One of the series provides a background for the evaluation and discusses program features and use. Part Two will discuss and analyze decompression computations generated by the algorithms.

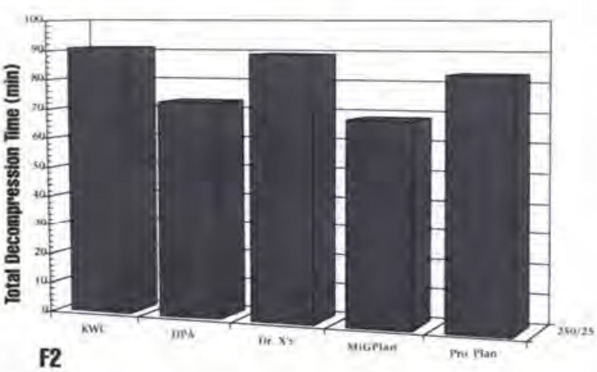
by RW Bill Hamilton and John T. Crea

DESKTOP DECOMPRESSION REVIEW



F1

F1 compares the total decompression time calculated by each program to that of the Canadian DCIEM air tables for a 30, 60, and 90 minute air dive to 100 fsw (31 msw). Note that though the variation in total decompression time becomes more pronounced as the the length of the dive increases. Maximum variation for the 90 minute dive is 33 minutes.



F2

F2 compares total decompression times for each program for a trimix 17/50 dive to 250 fsw (77 msw) for 25 minutes using an EAN 36 intermediate mix and 02 @ 20 fsw (6 msw). These are compared to the Key West Consortium Tables prepared by Hamilton Research Ltd. Note that all of the desktop programs yield shorter decompression times with a maximum variation of 23 minutes. For more information on trimix tables see "Trimix Report," by Michael Menduno, pg. 36.

Aquatronics, Dr. X's Dive and Deco Planner, by DEEP, Inc., and MiG Plan from MiG Technologies. We regard these programs all as a "first cut" at this type of capability, and in this review we try to recommend ways they might be made easier to use and their output more valuable.

HOW THIS EVALUATION WAS DONE

The purpose of these "desktop decompression planners" is to plan an exposure of people to pressure (a dive) followed by a planned return to the starting pressure (a decompression table), all of which will result in an acceptably low risk of decompression sickness. The authors, as "providers" of custom decompression tables, are obliged to be fair in our assessment. Even with some experience in decompression behind us, we found this task enlightening to say the least, and at times a bit frustrating. Both of us have developed and use sophisticated in-house programs for generating tables, one of which is Hamilton Research's DCAP© (Decompression Computation and Analysis Program) which is used in several laboratories, and in doing this we have encountered many problems and have seen the need for many of the features or capabilities of these planner programs. One of us (RWH) took the approach that a new user should not have to call for help in order to use the software, so we tried doing the evaluation in that manner, without using technical support from the developers.

We designed an array of dive plans that we felt would test the programs over the ranges where they would most likely be used. All programs seem to work, all took some effort to learn to use, and all presented some difficulties; we learned that our typical dives were not so typical. Tables T1-T3 summarize their operation and "user friendliness", computations, and information displays. More detail on computations, including gas consumption, and specifically on the conservatism or "J-factors" will be given in the next issue of *aquaCorps*. The conservatism or "J-factors" are critical, since they have a huge impact on the table generated. A table with any reasonable degree of conservatism can be generated with any of these programs (except MiG Plan; see description). The problem is, how does the user know what is right? More about that next time.

Figures, F1 and F2 illustrate some of the air and trimix decompression computations generated by the programs. These are compared to the DCIEM tables (air) and the Key West Consortium tables generated by DCAP (trimix 17/50 with EAN 36 intermediate mix and O2 @ 20 fsw/6 msw).

Note that the J-factors are all turned off or set as low as they go, so none of these would be recommended by their developers.

BACKGROUND AND TERMINOLOGY

Before discussing individuals programs, here is some fundamental terminology and information we feel should be available to the user.

Pressure units: Because the planners deal with **pressure**, we feel they should operate in **pressure units.** Since most Americans still use imperial units, the **foot of sea water,** fsw, is probably a basic unit of choice. A foot of sea water is normally defined as 1/33 atm (1/33 of a Standard Atmosphere, which is defined as 1013.25 mbar), with some slight variations by some (e.g., 33.08). The definition of the unit is not the issue, since variations among the common unit definitions are trivial from a physiological perspective. But decompression planners should produce **quantitative** results, and as such their units should be **precise** and **traceable** to a firm standard somewhere.

If metric units are used, the **metre of sea water,** msw, is universally defined as 1/10 bar or 10 Kpa. This makes the conversion factor between fsw and msw as pressure units equal to 3.2568 fsw/msw (but the conversion of units of length is 3.2808 feet per metre. *See Corps letters, a/c J5: 57-ed.).* The issue of fresh or sea water is a bag of worms, covered in the next installment.

None of the planners define the units they use; Dr.X refers to fsw, the others say "feet." All probably have small unit errors, which we regard as untidy but not physiologically significant.

Partial pressure symbolism: Another pressure-related term could be standardized. The symbol for the partial pressure of a gas as used by physiologists is a capital P, followed by a subscript identifier (such as I=inspired) and the chemical symbol of the gas. Thus P_IN_2 is the inspired nitrogen partial pressure, or just PN_2 with "inspired" implied. The use of "F" to mean "fraction" in the same sense is encouraged. A lower case p as used by chemists has another meaning (as in pH) so can be confusing and is therefore discouraged. Diving operations people may use "PP" to mean partial pressure; this is unambiguous, but we use and recommend the physiologists method of PO_2 for consistency.

Elapsed time display: Tables that present only stop times impose a handicap on the diver. A table should give the accumulated **elapsed time** to the end of each stop. In commercial diving, since the time to get the work done— *bottom time*—may not be known in advance the tables show **decompression time,**

the time since leaving bottom. These are easy to run; just punch the clock on beginning ascent and depart each stop at the indicated time. For tightly planned technical dives **running time**, the elapsed time since the beginning of the dive, works well also. Ideally the user should be able to get both decompression and running time at each stop. Another handy time is the **time to first stop**, since the diver needs to know this.

Oxygen limits: All the programs deal to some extent with oxygen exposure limits and issue warnings when limits are exceeded. Sometimes this is overdone, with so many warnings the user will ignore them. Dr.X beeps a warning whether the dive exceeds limits or not. For CNS oxygen toxicity warnings, DPA, Pro Planner, and MiG Plan use the fraction of the NOAA limits (described in Kenyon and Hamilton, 1989), a CNS toxicity fraction (or "CNS oxygen clock"). Dr.X (apparently) warns when a set PO_2 limit is exceeded. All but MiG Plan accumulate OTU's (oxygen tolerance units); these are not important for any but the most extreme dives.

Narcosis: A widely held assumption is that oxygen plays no role in narcosis, much the same as it does not contribute to decompression. Evidence, other than anecdotal, that this is true is lacking (Linnarsson et al, 1990). Several programs calculate an equivalent narcosis depth based on PN_2; we advise that this be used with caution. It might be better to assume that the narcotic effect is due to both N_2 and O_2.

DESIRED FEATURES

A certain few features, in our opinion, are desirable for programs that generate decompression tables.

None of the programs allow the user to modify a previously entered dive. It seems like it should be easy to include as **defaults** the values for the last dive calculated, so the user could repeat the dive with desired changes; this would be extremely beneficial. For even experienced computer users the ability to "escape" back to a familiar menu is essential once a mistake is made. DPA has a "go back" code, and Dr.X a code for return to main menu, but none has a real "escape." Another essential feature is the ability to save a calculated table to a file, with the filename or table name showing on the table printout also. For existing programs that do not allow this (Dr.X and MiG), utilities such as PRN2FILE enable (some) printer output to be directed to a file. The printed table should also show the parameters or settings used to generate the table, and should be dated.

A computation just as important as the decompression table is the **volume of breathing gas** used on a dive. All these programs except Pro Planner provide esti-

T1: COMPUTER OPERATIONS

Feature	DPA	ProPlan	Dr. X	MiG
Installation	Program or copy files	Use program only	Program or copy files	Program or copy files;
Manual	Loose leaf, 50 pg	Disk, 5 pg	2 pg	10 pg
Examples given, with expected output	Many	None	None	Sample screens
Copy protection	Yes, uses h/w "key"	Yes, must install	None	None
Troubles with installation	"Key" not seen on Dell laptop.	A wrong error message, not critical.	Yes, must be careful	None, easy. None
Waiver acceptance required	Opening screen, detailed	Yes, short	Opening screen, detailed	Opening screen.
Program personalized	Name on tables	Yes, opening screen	Yes, opening screen, on screens, and tables	Opening screen, in waiver
Escape to main menu	Only at end of table; possible to back up	Not often	At any time by typing m, but it forgets mixes	No
Works with %O_2 (not just inerts)	Yes	No, uses inerts only	Bottom, no; EA, yes.	Yes
Can redo previous dive with changes	No	No	Can reuse mixes right away only	Can save mix definitions
Sensible defaults	Not intuitive; does not remember gases	Yes, but all stops have to be keyed in	Only a few	Remembers mixes during a dive
Whole table shows on screen	Scrolls off; view with DOS utility program	Use Print command to view table	No, have to print	Can scroll it up and down
Can save table to file	Saves whole session; overwrites old file	Yes	No	No
Printing	Have to set before running dive	Dot and laser, graphics; good control.	Can't print after viewing	Yes, does not print loadings
Telephone support easy	Not encouraged	Number not listed	Phone number on screen	Yes, listed
Error handling	Poor. Often needs 3-key; but can go back	Can't go back	Tolerant; can't go back	Can't go back; tolerant
Trouble shooting info	Yes, good	None	None	None
User friendliness	Poor at first; not so bad after practice; not intuitive	Pretty screens. Can't go back	Straightforward; very mix oriented	Crisp and simple, few options

mates of gas usage as a function of depth and a predetermined surface rate of consumption. Dr.X and DPA allow a different consumption rate for different stages of the dive. **Utilities for mixing and for topping partially used tanks** are given, but even the best of these (Dr.X) is limited, since the only reuse of a partly empty trimix tank is by adding air; use of pure inert gases or oxygen for topping is best left to the commercial gas suppliers.

There seem to be two approaches a program (or dive computer) can take with regard to informing the user about what it is doing. One is to appear as a **"black box"** which takes input and spits out a table, without telling what goes on inside the box. The other is to be completely **explicit as to what equations are solved.** It would appear that the black box approach puts the burden on the designer to provide a proper decompression, while the latter approach only obligates the program to solve the equation correctly.

We strongly recommend the explicit approach. We would like to know the equations solved in making the decompression calculations. Where the implementation is straightforward according to the 1984 book (on which these programs are based), it may be sufficient to reference it, but if there are changes we want to know them. We especially want to know what the "J-factors" (the conservatism factors) do and how they are calculated. Only the Pro Planner gives details to the extent of including half times, but all reference Bühlmann.

Not every user will be able to evaluate what these equations mean, and even those who do may not be able to judge easily whether the profile generated is reliable. Unfortunately, developers of programs of this type do not (and cannot) provide the support in the realm of decompression physiology to be able to give the user all knowledge needed for using the programs and their output. This has to come from substantial experience and/or from serious technical diving training courses; unfortunately not all the available courses adequately dispense this level of training.

More details on the Bühlmann algorithm (1984) and some philosophy on decompression planning programs will be given in the second part of this series.

DISCUSSION OF THE PROGRAMS

Tables T1-3 summarize the salient features of each of the programs. A discussion of each is given below.

Dive Profile Analyzer (DPA): DPA comes with a loose leaf manual, the only "real" manual in the group. However, it has the figure references all mixed up (unnerving for a decompression program), but it has many examples. A manual is needed because the program is not intuitive and the user needs guidance at first.

Coded input data separated by commas is entered on a command line, following codes shown in a box on the screen. The coding is clever, but initially one feels the data could just as well be entered in response to prompts. However, command line input is faster than menus after a little experience, so this cryptic and initially unfriendly method is actually quite effective. A "quick review" page would be helpful.

DPA provides a comprehensive table, with running time at the beginning and end of each stop, but does not show decompression time. One inconvenience is that to see the table the user has to exit to DOS and run a program to view the file. The He J-factor would not set at 0 but it will accept 0.01. DPA runs a CNS O_2 toxicity clock, but the output is in a warning, not on the table. The table identifies the third column and PO_2 levels as "bar," but the values in the column are atmospheres, a bit misleading.

PRO PLANNER

Without doubt Pro Planner had the slickest appearance, with a color graphics menu that includes little bubbles rising, a good reminder of what we are doing. Input is intuitive and has flexibility, but every stop has to be entered, and even though it is done with defaults it can be tedious and this seems unnecessary. Having to enter only the inert gases rather than the oxygen percentage is to us inconvenient.

The model specifications say Pro Planner has 16 compartments and 16 tissues, adding to the confusion (these should be called compartments consistently). The specs mention capability with rebreathers to 300 msw or 970 fsw (with an O_2-N_2 mix!), which to us is a bit disconcerting because that makes it look more like a computer game than a serious program; *they can't be serious!* Even trimix to 200 msw (=651 fsw, but it says 640) in our opinion is well beyond the scope of this type of program to handle, if for no other reason because of overall operational complexity.

The table screen is well done, with loadings and both a current and a history graph as well as the table (but why is the history on the right and the current dive on the left?). Scales on the graphs are inconsistent, done to fill the space but it makes them hard to compare. Stops are not at even 10 fsw increments, causing one to wonder why. A big disappointment with this program is that the table has no elapsed time.

Nowhere does it tell the user that a laser printer can be selected (by the Printer selection on the main menu), so we dusted off an old 9-pin printer, which worked but very slowly; this proved to be unnecessary as it has two laser printer choices, small and big print (nice!).

T2: COMPUTATIONS

Feature	DPA	ProPlan	Dr. X	MiG
Algorithm	ZH-L16 (not sure of which version)	ZH-L16	ZH-L16, modified (not stated how modified)	ZH-L12 (also a 12 cmpt model, source?)
Halftimes given	No	Yes, but not limits	No	No
J-factors	Increases each inert gas by a %	Increases inert 1% for each 5% factor	"Safety factor" in %; increases bottom time; different with air	4 levels; more conservative limits O2 also
Descent rate control	Instantaneous, can step down.	Instantaneous, can step down	66 fsw/min, set	Instantaneous, can step down
Ascent rate control	Instantaneous	10msw/33fsw per min	33 fsw/min, set	Not given
Can change mix in dive	Yes, at any stop	Yes, at any stop	Select in advance; only 1 trimix allowed	Some options, not all
Constant PO_2 (rebreather)	Yes, called "macro"	Yes	No	No
Can "position" diver though a profile	Yes	Yes	With difficulty	"Load" allows profile freedom but not mix control
Retains loadings to do repetitive dives by gas loading	Says not to do it; have to "position" thru first dive	Yes, well developed	Not possible	Yes, well developed
Multilevel dives	Yes	Yes, well developed	Not possible	Yes, well developed
Flying after diving	No	Yes	No	No
Basis for EAD given	n/a	Not given	n/a	n/a
Diving at high elevations	No	Yes, good to 11500 feet elevation	No	No. A version that does this is available.
OTU count	Yes, by stop & at end, warns on % exposure	Yes, end of dive	Yes, at each stop (615 limit inappropriate)	No
CNS oxygen warning	Only on PO_2 level	Yes; gives % exposure	Only on PO2 level; beeps even when O2 low	Yes, gives % exposure
Gas consumption	Yes, bottom & decom	No	Yes, well developed	Yes, only one level
Calculates tank topping	No	Yes	Yes, with air	No

DR.X

Dr.X takes the "no frills" approach to the screen, using straightforward and intuitive prompts. There is no capability for doing multilevel and repet dives, however. There is a mix selection algorithm which seems designed to keep the new user out of trouble. A nice feature is that one can escape to the main menu by typing "m" at any point, but the dive has to be started over. The gas definitions can be used again, if done right at the end of a dive, but the use of appropriate default values is minimal.

The table is comprehensive, has instructions and warnings and includes running time, but the printout has a copyright statement which seems to be printed right over part of the warning section. The warning area is cluttered and it is an effort to pick out the data. Asterisks mark points where there is a high CNS toxicity risk, but how this is determined is not described, and as mentioned, it beeps even when there is no violation. The table includes a calculated "one minute emergency ascent" which is not the same as the first stop depth; its meaning is not clear to us. The total stop time is given, without the travel time, which is not as useful as total decompression time would be.

A good part of this program and its utilities is directed toward gas management, selecting, mixing, and keeping track of gas consumption. We are told a manual is on its way.

MIG PLAN

The screen has gas definition on the left, a character-based loadings chart in the middle, and a rather cryptic table on the right. The program will select appropriate mixes, in many cases without real control by the user, based on PO_2 and air-equivalent narcosis (see discussion above). The user does not get to dictate gas switches specifically, but rather defines the range of use of each mix and the program does the switching; these appear to be appropriate, but may not be what the user wants. It seems to be possible to enter inappropriate gases without a warning on entry. The program has a "load" function which can be used for profile positioning rather easily. It will retain the loadings over a surface interval, permitting repetitive dives based on gas loading. It will not allow decompression to an intermediate depth, only to the surface. Only one gas consumption rate can be used. Bottom time is defined differently by MiG Plan, encompassing the interval between leaving surface and arriving at first stop. This also makes the displayed run time non-standard.

The table only includes depth, running time and mix name, which is the bare minimum a diver needs but its value for analysis is limited.

The J-factor choice in MiG Plan is limited to certain categories, not a numerical value. The more conservative choices also limit the PO_2 which can be used, perhaps protecting the user against high oxygen exposure but greatly limiting the flexibility of the program. The commentary in the small manual is appropriate in warning about this program's providing the capacity to do dangerous things; the solutions are generally bucked

T3: DISPLAYS

Feature	DPA	ProPlan	Dr. X	MiG
Gas loadings displayed	No	Yes	No	Yes, character graph
Time to first stop	By subtraction only	No	Yes; added to bottom time	No
Decompression time at stops	No	No	No. (But it does show on screen display)	No. And no stop times!
Running time at stops	Yes	No	Yes	Yes, non-standard
Total decompression time for whole table	Stop & travel totals shown separately	Yes	Stops only	No
Total running time	Yes	No	Yes	Yes
Time of day display	No	Yes	No	No
User can put comments on table	No	No	No	No
J-factors used show on table	Yes	Yes	Yes	No
Filename shows on table	Yes (session ID)	No	n/a	n/a
Date shows on table	No. Random code # ?	No	No	No

Illustration by: Jean-Pierre Imbert

off to the training courses, but some bad practices such as yo-yo, reverse, and multiple deep repetitive are mentioned.

CONCLUSIONS

These programs are a first step toward filling the gap between traditional decompression tables and on-line, realtime dive computers. They permit user-controlled dive planning for many special cases where presently there are few options. No one can say whether they produce "safe" output, and people in the decompression business are reluctant to use that word with even their most reliable tables. Reliability depends on the degree of conservatism. We do not worry nearly as much about whether the programs can calculate good tables as we do about whether the users can make the judgement as to when they are good. Details about this and the table computations in general will be covered in a later article.

None of the programs at present qualifies as a "best buy," but they all represent a good start. They are usable now, with some inconveniences and difficulties. The developers see the problem from different perspectives, and ours are different from those. We would like to see, just for the record and not for daily use, more about how the calculations are done. One of us (RWH) is committed to a display of decompression time, but running time is a close second and is best for many of these applications. All the programs could be easier to use; one way they could all benefit is to retain the data from the last dive as defaults for the next one, enabling similar dives (e.g., same depth and different bottom times) to be done. More to come.

Dr. R.W. Bill Hamilton is is a diving physiologist and principal of Hamilton Research Ltd. with over 20 years of decompression management experience in the hyperbaric and aerospace industries. He can be contacted at: HRL, 80 Grove St., Tarrytown, NY 10591-4138, f:914.631.6134. John T Crea is an anesthesiologist and principal of Submariner Research Ltd. which provides custom tables and consulting. He can be contacted at: SRL, PO Box 1906, Bainbridge, GA 31717, f: 912.246.9349. Both are contributing editors to aquaCorps Journal.

More Information

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Desktop Software

Dive Profile Analyzer.
Author: Corey Berggren Cybertronix, Inc., 3435 Redbud Drive, Knoxville, TN 37920. p: 615.977.0360. Australia: High Tech Divers p: 61.2.418.9507 f: 61.2.418.9513

Pro Planner.
Author: Kevin Gurr. Aquatronics, 42 Marsh Road, Thatcham, RG13 3QR, England, U.K. p:44.635.869.185, f: 635. 869.185 US: IANTD, 1545 NE 104th St., Miami Shores, FL 33138 p/f: 305.751.4873

Dr.X's Dive & Deco Planner.
Author: Sheck Exley. DEEP Inc., Route 8, Box 374, Live Oak, FL 32060 p: 904.362.7589

MiG Plan.
Authors: Jody Svendsen and Dan Nafe. Mig Technologies, 2000 NW 88th Court, Miami, FL 33172 p: 305.594.4994.

"Telepresence" was marvelous, but it could sometimes be a dangerous illusion. You might believe you were experiencing a hundred percent of some remote reality but it was only ninety five percent— and that remaining five percent could be vital: men had died because there was still no good way of transmitting those warning signals that only the sense of smell could detect.

Arthur C. Clark, Ghost from The Grand Banks

Dive Profiler

by Karl Shreeves

"What was your profile?" the divemaster asks.

"60 feet for 55 minutes. Great dive."

In recreational, technical and other self-contained diving, conversations like this probably take place hundreds of times daily around the world. The diver will record "60 feet, 55 minutes" and proceed accordingly. Repetitive dives will be planned based on "60 for 55," and if the diver suffers decompression illness, the profile goes into the record. Yet self-contained divers rarely conduct square wave dives; calling maximum depth and time, "the profile" is nothing more than a reference to tables —a bit archaic considering the widespread use of computers.

Enter the Dive Profiler from ORCA/EIT which works in tandem with the Delphi and Phoenix computers. With the Profiler, the dive profile is, well, the actual profile—depth and time sampled in two minute intervals.

FEATURES

In a nutshell, the Dive Profiler allows you to download profile data from an Orca Delphi or Phoenix computer through an optical data reader. You match the data with other manually-entered dive information, such as dive site, temperature, gas consumption and notes, to create a dive log.

Profiling a dive is easy. Call up a log and a depth/time graph appears with a Delphi/Phoenix face replicated along side. Click the "go" arrow and the profile draws itself across the graph (you can vary the rate) with the Delphi/Phoenix reading out as if you were making the dive. You can pause and resume the profiling at any time. Dive Profiler will print both text logs and graphics. Multiple diver logs can be maintained and the data can be exported to other computers.

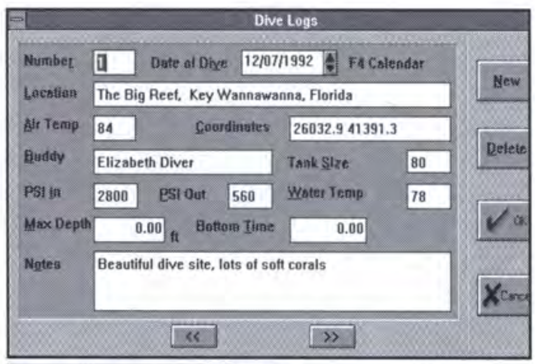
The Profiler runs on PC-compatibles operating with a "Windows" (3.0 or higher) environment which may be a drawback to some users. Windows is a memory guzzler, making it not exactly ideal for meagerly-powered machines (A 386 and 2MB RAM is recommended). Another concern is the need for multiple serial ports (one for the mouse, one for the Data Reader/printer).

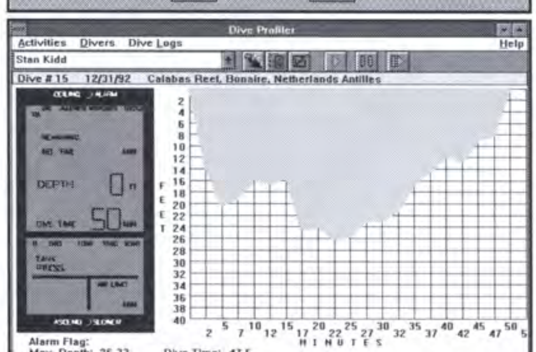
Applications

In return for slightly "stiffer" hardware demands, the technology represented by Profiler may redefine the notion of "profiles" forever. Dive Profiler and the Phoenix have immediate application in technical, research and recreational diving in areas such as decompression research, runtime confirmation, mapping, training and improving log accuracy.

Eventually this technology may enable any diver to participate in an industry-wide decompression database. It's simply a matter of time. And depth.

Note that the next version of the Profiler, scheduled for release in Q4, 1993, will reportedly offer a dive simulator based on the ORCA computational algorithm—ed.)





A new addition to aquaCorps advisory board, Karl Shreeves is coauthor of "The Recreational Divers Guide to Decompression Theory, Dive Tables and Dive Computers," along with Dr. John Lewis. Shreeves is the Manager of Technical Development at PADI and serves as the liaison to the technical diving community. He can be reached at: PADI, 1251 East Dyer Rd., #100, Santa Ana, CA 92705, f: 714.540.2609, GEnie: K. Shreeves.

More Software

For photographers the job of organizing and labeling your slides just vastly improved. The **CRADOC CaptionWriter TM IV** is a wonderful resource tool which helps you categorize and label your slides. If your tired of labeling slides by hand or wondering where that favorite slide went to, this time and money saving tool is for you. Contact: Perfect Niche Software Inc., 7100B E Main, Scottsdale, AZ 85251, ph: 602.945. 2001, fax: 602.945.1023.—*submitted by Wes Skiles.*

Ocean Diving has just released **"Mix Master,"** a software package that enables qualified mix users calculate appropriate gas mixes for a given depth including EAD, END, and OTU loading calculations. The software will also display amounts of gas required to achieve a desired EAN or helium-based mixture. Mix Master runs on IBM compatibles. Contact: Ocean Diving, 750 East Sample rd, Pompano Beach, FL 33064 p:305.943.3337

VisionTech has just released a graphical 'no-stop' decompression and gas supply simulator, **PDS** (Professional Dive Simulator) based on the USN Air algorithm with an EAN 32 conversion. Virtual diving is here. Contact: VisionTech Inc., PO Box 1416, Mentor, Ohio 44061 p: 800.858.8317.


Photo by: Dan Burton

BLUEPRINT FOR SURVIVAL REVISITED

SAFETY GUIDELINES FOR "EXTENDED RANGE" DIVES

by Michael Menduno and Capt. Billy Deans

Following the tragic "technical-level" accidents that occurred last summer in the U.S. (Menduno, 1992), the authors and other members of the community felt that a basic set of operational guidelines were needed to guide the conduct of "extended range" diving. Though initial training standards had been established by the American Nitrox Divers Inc (ANDI) and the International Association of Nitrox & Technical Divers Inc. (IANTD), and are continuing to evolve, there is currently no set of agreed to operational guidelines similar to those developed by the cave and scientific communities.*

This paper sets out a basic set of operational guidelines based on what we perceived as the "best" practices from the technical community drawing heavily on accident analysis techniques developed by the cave community. As such they represent a starting point for the development of "community consensus" guidelines for technical diving. We offer the following for consideration.

risk management

About twelve to fifteen years ago in response to the then growing number of fatalities, the cave diving community developed a set of safety principles based on the then new tool of "accident analysis." Later refined by pioneer Sheck Exley and elucidated in his book, *Basic Cave Diving: A Blueprint For Survival* (Exley,1979, 1986), accident analysis is a means to rigorously dissect an accident into it's constituent parts with the goal of determining "what went wrong." Applying this tool to cave diving it was found that most diving accidents could usually be attributed to a primary causal factor and typically one or more contributing factors. What's more is that these factors could be "boiled down" into five basic cave diving safety principles; be trained, utilize a continuous guideline to the surface, manage your gas according to a third's rule or better, don't dive deep (on air) , and carry at least three lights. A sixth principle, known as "Eternal Vigilance," states that, "Anyone Can Die At Any Time On Any Cave Dive." Accident analysis and these resulting safety principles have become the cornerstone of cave diving safety ever since.

Numerous other analyses of sport diving accidents have been conducted following the early cave diving work. In 1989, Mano and Shibayama, published a study titled, "Aspects of Recent Scuba Diving Accidents," (Mano and Shibayama, 1989) which analyzed 264 fatalities and 319 incidents of decompression illness and arterial gas embolism. According to the authors, over 45% of sport diving fatalities that occurred were due to "reckless diving" or "lack of technique." Most appear to have been preventable. In another study, Chowdhury, in affiliation with the National Underwater Data Center (Chowdhury, 1989) conducted an analysis of wreck diving accidents. His conclusions were that 73% of the accidents involving wreck penetration were due to the "lack of a continuous guideline," while 42% of the fatalities that occurred external to a wreck were due to "Out of Gas" emergencies.

In 1990, Exley, revisited his earlier work in a paper published in *Underwater Speleology* (Exley, 1990). Based on the recent trends in accidents, Exley concluded that perhaps too much emphasis was being placed on the basic cave diving principles in light of more recent tools and techniques being employed by cave divers (ex. mix technology), and that an expanded list of safety recommendations should be developed.

Exley's conclusions provided motivation for this paper. Our approach was to attempt to identify and address the factors that could potentially result in diver injury or death building on the cave diving safety principles and practices from the community. The resulting guidelines are organized into seven categories; Requirements, Training, Gas Supply, Gas Mix, Decompression, Equipment and Operations.

REQUIREMENTS

The generalized requirements for conducting technical dives were aptly summarized in the form of the acronym, AKTEE by technical operator, Jim Baden. These are:

- **A—Attitude:** Why are you doing this? A proper attitude is essential to conducting technical dives safely. There is no room for recklessness or machismo.
- **K—Knowledge:** Without the proper knowledge there are no options when problems occur.
- **T—Training:** Skills must become second nature— a part of *muscle memory.*
- **E—Experience:** Experience is *exposure and environmental specific* and takes time to build. Extensive wreck diving experience does not qualify a diver for cave diving and visa versa.
- **E—Equipment:** Every dive requires an appropriate set of tools.

TRAINING

Technical training is an "ongoing" process similar to training for an athletic season or flight training. Continual practice is the key. Completing a formal course is a good first step, but is only a starting point. It does not in itself prepare you to make the dive. Technical diving is a discipline, not a card.

1. ***Always be prepared and trained for the dive you plan to conduct.*** Ask yourself if you, and your partner, meet the **AKTEE** criteria.
2. Review and practice ***emergency procedures*** frequently so that they become second nature.

****Extended range*** diving refers to self-contained sport diving beyond the established recreational/sport diving limits; (US) no-stop air dives in an open-water environment to 130 fsw. (UK) limited air decompression dives to 50 msw.

GAS SUPPLY

Ensuring adequate gas supplies is the major constraint factor in self-contained diving and represents the single largest risk factor. In particular, planning and carrying adequate gas reserves is critical.

3. Always dive an appropriately ***redundant breathing system*** (minimally first and second stage redundancy) in an *overhead environment,* or when diving in open water beyond about 60 fsw (18 msw).
4. ***Pre-plan and calculate the gas required to conduct the dive*** (Gas requirements = planned consumption plus required reserves) and dive your plan. Always dive your bottom gas using ***at least the Rule of Thirds*** in an overhead environment, or a suitable equivalent in open water, depending on the operation. There should be sufficient reserves for the dive team to exit safely in the event one diver suffers a "catastrophic" gas loss. For "extended" open water dives, the consensus seems to be to reach your first decompression stop with one third of your bottom gas remaining.
5. Plan ***at least a 33% reserve*** (1.5 x planned usage) for your decompression gas. Depending on the operation, decompression cylinders should be equipped with redundant regulators.
6. When possible, ***carry all the gas you will need*** for the dive unless it can be ***reliably staged,*** depending on the operation and environment. Note that the ability to reliably stage gas is one of the major differences between cave and wreck diving. **In open water diving the goal is to be "self-sufficient," to the maximum extent possible.** Based on an analysis of gas logistics, the *self-sufficiency "breakeven point"* for extended open water dives appears to be about 250-300 fsw (77-92 msw) for a two person team depending on the duration of the dive. Open water dives beyond this require an extensive support team and effective communications.

GAS MIX

Mix technology is a tool designed to improve underwater safety and performance when properly applied. The most critical factor in special mix diving is oxygen management due to the risk of a CNS toxicity convulsion.

7. Always ***dive the safest possible mix(es)*** for the dive you plan to conduct.
8. Always ***analyze and label*** your gas and regulators before making the dive. Make sure you know what you are breathing.
9. **Maintain your PO2s *below 1.5 atm during the working phase of the dive and anytime more than light work is being done***, boosting oxygen levels to a *maximum of 1.6 atm with care, during resting decompression.* The community standard today is to run travel and bottom mix at about 1.2-1.45 atm, depending on conditions and the operation. Take regular ***"air breaks"*** as a safety hedge every 20-25 minutes when breathing oxygen. As succinctly summarized by Terry Billingsley (Hamilton, 1985), *"CNS Toxicity is like sand beside the road. If you stay on the road you won't get into trouble."*
10. ***"Just Say No" to nitrox mixes ("air") beyond about 180-200 fsw (55-61 msw)*** or less, depending on the operation and environment. *In particular keep equivalent narcotic depths (END) as shallow as operationally and economically feasible, preferably 150 fsw (46 msw) or less.*

DECOMPRESSION

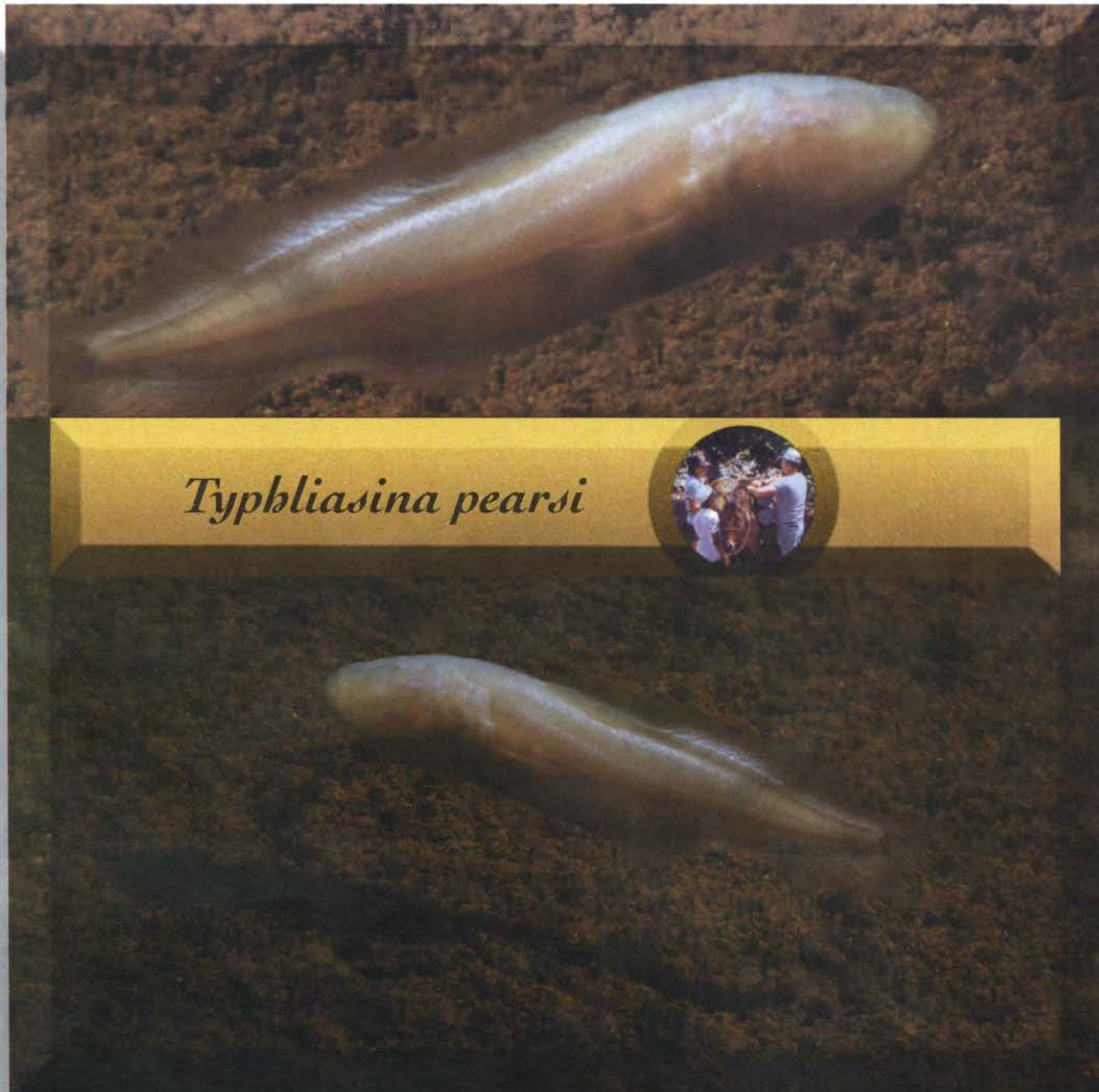
Decompression illness is not an accident. It happens and will continue to happen as a predictable part of diving.

11. Always use appropriate and ***reliable decompression methods and tools*** for the dive your planning to conduct and be ***conservative.***
12. Utilize a ***hyperoxic mix for decompression*** (ex. oxygen and/or suitable EAN mixes) whenever possible when conducting a staged decompression exposure. Note that the technical community has become much more vigilant in the use of oxygen or EAN for decompression. Oxygen at 10 and 20 fsw (3 and 6 msw) is preferred. Air, and to a lesser extent EAN mixes, are generally regarded as inefficient at reducing decompression risk (Vann, 1992).
13. ***Limit oxygen decompression to 20 fsw (6 msw) or less (max. PO2=1.6 atm)* and *use care.*** The diver breathing a decompression mix or oxygen should avoid anything that would increase the liklihood of CNS oxygen toxicity, or specifically, anything that might raise the diver's carbon dioxide level. ***Use an oxygen regulator 'guard' to prevent the accidental use of pure oxygen at depth.*** Color coding and labeling are insufficient safeguards.
14. ***Plan for and always be prepared to deal with decompression illness*** (DCI). In particular have *plenty of oxygen* immediately available for treatment after any diving operation and know how to use it. *Many people believe that low cost portable on-site chambers will eventually become the order of the day.*

EQUIPMENT

Your equipment is your life support system which allows you to survive in a physiologically hostile environment. Second only to breathing equipment in importance, safety lines and a decompression line system are critical to diver safety.

15. ***Always use the best possible equipment*** that is well-maintained and ***appropriate*** for the dive you plan to conduct and the environment. Redundancy on all essential subsystems is key. In particular, ***always carry appropriate emergency equipment and know how to use it,*** for example: three lights (overhead environment), a decompression reel & lift bags (open water), surface signaling device (open water) and a bail-out bottle (when diving as a *team of one*)
16. Always use a ***continuous guideline*** when diving in an *overhead environment,* and/or a ***decompression line system*** when conducting extended and/or deep open water dives. Note that conducting multi-level extended open water hangs without a safety line home is tricky and can be hazardous, particularly when using hyperoxic decompression mixes, where depth control is critical.



Photography by Lalo Fiorelli • Imagining by Mike Bielinski - FERMI Graphics, Key West © 1993

Typhliasina pearsi—the "Mexican Blind Cave Fish"— was discovered by Hobbs in 1936. Approximately five inches long, Typhliasina is a trogiodyte, that is an animal adapted to the cave environment exhibiting the common charateristics of lack of functional eyes and loss of skin pigmentation. It is believed that this is the first time an in-situ picture of this elusive fish has been published.

Typhliasina was photographed in "Satan's Silk Hole" on the syphon side of the Carwash Cenote in Q.ROO Mexico, a low flat area covered with black silt an arm's length deep. The project required nine dives on an 80 fsw schedule using double cave-configured eighties. The photography was extraordinarily difficult due to silt outs and the constant movement of the fish. As a result, it was impossible to use the viewfinder. The camera was prefocused to six inches and operated in a "point and shoot" mode. The picture was made with a F-3 Nikon, 55 mm macro lense in an Aquatic housing using two strobes. Film was professional 200 kodachrome at 1/80 sec. and F22.

Lalo Fiorelli is a fine art photographer specializing in the underwater cave environment. He can be contacted at: 250 Rocky Road, Soquel, CA 95073, f: 408.464.1854.

17. If possible, wear breathing equipment that allows you to ***survive an underwater convulsion/loss of consciousness,*** such as a full face mask system or retaining strap. The use of full face masks is growing the will likely become a standard for many technical diving applications due to their many advantages.

OPERATIONS

Technical dives are ***operations:*** *a project or venture involving; planning, preparation, organizational structure, the use of proper equipment, teamwork, competent execution, and the capability of responding to emergencies effectively and immediately. Diver safety is always the first priority. In terms of support requirements, technical dives fall somewhere in between recreational dives and commercial operations. Note that all dives are operations. In the case of "recreational diving," the requirements are minimal.*

18. ***Pre-plan all aspects of the dive you intend to conduct.*** Design your operation with the goal of being able to provide ***effective and immediate assistance to a diver in distress at any point in the dive.*** In particular, ***be prepared for the worst,*** and always have ***plenty of oxygen*** on hand and know how to use it. Above all, if your not prepared to do it right, don't do it.
19. ***Always dive as a team,*** utilizing ***surface support personnel,*** *and when appropriate,* ***in-water support divers,*** whenever possible. In particular, designate an ***operations manager***, who is responsible for overseeing *diver safety* and *record keeping.* Note that The "buddy system" is not reliable enough for extended range diving. A ***team approach*** is required though a *team of one* is perfectly acceptable in many circumstances, depending on the operation and environment. Above all, always honor rule number one of team diving, ***Anyone can "call" the dive at any time for any reason*** (Anyone can die just as easily.)
20. Utilize an effective ***communications system*** between the dive and support team whenever possible. *In the future, wireless communications systems will become standard.*
21. ***Remember, YOU, and YOU ALONE, are responsible for your own safety. Never permit overconfidence or peer pressure to allow you to rationalize compromising safety procedures.*** *It could ruin your whole day.*

Michael Menduno is the editor and publisher of aquaCorps Journal. *He can be contacted at aquaCorps, PO Box 4243, Key West, FL. 33041, f: 305.293.0729. Capt. Billy Deans is the owner of Key West Diver Inc., Technical Diving Center. He can be contacted at KWD, MM4.5, US #1, S.I., Key west, FL 33040, f: 305.294.7612.*

Special thanks to the following individuals and organizations for their interest and input on this work; Jim Baden, Ed Betts, Bernie Chowdhury, John Crea, Sheck Exley, Lalo Fiorelli, Steve Gerrard, Dr. R.W. Bill Hamilton, Lad Handelman, Lamar Hires, Jean-Pierre Imbert, Jim King, Dick Long, Tom Mount, National Association For Cave Diving, National Speleological Society—Cave Diving Section, Karl Shreeves, Joel Silverstein, Lee Somers, Dr. Bill Stone, Dr. Richard Vann and Hal Watts.

Reference Information:

Sheck Exley was one of the key individuals responsible for developing and applying "accident analysis" to cave diving. His book, ***Basic Cave Diving: A Blue Print For Survival***, 5th Ed., 1986 is "required" reading for all technical divers. You can obtain a copy from the Cave Diving Section of the National Speleological Society, Po Box 950, Branford, FL. 32008.

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INCIDENT REPORTS

OXYGEN: GOOD, BAD, AND UGLY

An aquaCorps report

BOTANY BAY, AUSTRALIA

1993 February— A diver experienced an out-of-gas emergency as a result of equipment failure, lost buoyancy control during descent and blew to the surface following a 18 minute, 207 fsw (64 msw) air dive on the *SS Woniora*, omitting 44 minutes of decompression. The surface support team returned the diver to the water within five minutes for in-water oxygen therapy beginning at 20 fsw (6 msw). After completing 30 minutes of oxygen decompression at 20 fsw (6 msw), she ascended to 10 fsw (3 msw) where she completed an additional 30 minutes. She surfaced without apparent symptoms, was placed on surface oxygen and evacuated to a hyperbaric center which was 30 minutes away.

The diver presented mild neurological decompression illness on admission and was treated on an USN Table 6 with two follow up treatments of two hours each at 30 fsw (9 msw) on subsequent days. She was discharged three days later with no apparent residual symptoms. Although in-water therapy was not condoned by hyperbaric officials, they stated that the diver probably would have presented in a far more serious condition had it not been carried out.
—Submitted by Rob Cason, Fun Dive Centre, Sidney, Australia.

MERIDA, MEXICO

1993 March— A full cave and nitrox instructor suffered an oxygen convulsion during a deep air dive in a sink hole in Mexico and drowned. His partner who experienced CNS toxicity warning signs during the dive and a safety diver survived. The two later recovered the body.

The team had planned a 20 minute air dive in excess of 230 fsw (71 msw)— the depth of the saltwater halocline— in a cavernous open-water sinkhole near Merida on the Yucatan Peninsula. Because of the difficulty in obtaining helium mixes in Mexico, the team decided to conduct the dive on air followed by oxygen for decompression. Both were experienced deep divers. A weighted descent line was rigged for navigation and for staging oxygen and extra air cylinders. The safety diver was to descend with the team to 220 fsw, ascend to a shallower depth and wait for the dive team.

After a long slow descent past the halocline, the team tied into the descent line to explore the well at a leisurely pace. Informed sources estimated their maximum depth to be close to 300 fsw (92 msw) (*A PO2 in excess of 2.0 atm-ed.).* The surviving partner experienced a tingling in his lower lip and turned back to call the dive only to see the diver headed back as well. When he reached the line, he sensed that the diver was in trouble. The diver grabbed the line and began a hurried hand-over-hand ascent. The partner reached the diver, gained control and they began to ascend together. The diver continued to pull on the line creating slack and getting himself tangled. His partner cut him free. The diver then darted got tangled again and apparently convulsed. By the time his partner reached him the diver's regulator was out of his mouth. At that point they were still deeper than 230 fsw (71 msw). After repeated attempts to force the regulator back into the diver's mouth with no success, the surviving partner realized the diver "was gone" and leaving the body entangled in the line, ascended to complete his decompression. Following decompression, the partner and safety diver were able to pull up the line and recover the body.

POMPANO BEACH, FLORIDA

1993 March— An experienced 47 year old spearfisherman apparently switched to his oxygen regulator by mistake while chasing down a grouper at about 220 fsw (68 msw) during a deep air dive, convulsed and drowned. He was found on the railing of the RB Johnson with his regulator out of his mouth by his partner, who was reportedly diving trimix. The body was later recovered by the charter boat captain.

The diver was wearing twin "independently configured" 100 cubic foot cylinders, and an E-cylinder oxygen pony for decompression. Using this configuration, a diver must repeatedly switch regulators during the dive in order to balance the gas supplies. Though the diver used a distinct oxygen regulator which was labeled in green, his primary, secondary and oxygen regulators were banded together and mounted over his right shoulder. It is believed he mistakenly switched to his oxygen regulator in the heat of the chase (A PO2 of 7-8 atm), having speared his first grouper at 240 fsw (74 msw) earlier in the dive. He convulsed, spitting the regulator out of his mouth and drowned. Vomit and blood were found in his mask.

ST CROIX

1993 May— A deep air diver was reported missing and is presumed dead after he failed to return from an afternoon solo dive. The diver had been training for some time in hopes of setting a new record for deep air diving and had spoken about his plans to several individuals in the States who tried to dissuade him. According to local observers the diver had made air dives in the 470-520 fsw (144-160 msw) range, qualifying him for *some* kind of record.

The diver was last seen late on a Wednesday afternoon when he typically made solo dives. Later, friends found his car parked near the dive site, Twin Palms, and reported him missing when he did not show up by 9:30 pm. The local dive store apparently said he went out a 4:00 pm. Search divers were unable to find the body.— *Excerpted from Compuserve and the* "Virgin Island Daily News."

KEY WEST, FLORIDA

1993 May— A diver mistakenly switched to his "labeled and color-coded" oxygen regulator instead of EAN 36 at his 90 fsw (28 msw) decompression stop following a 25 minute exposure to 210 fsw (64 msw) conducted on trimix 17/50. The diver 'seized' approximately four minutes later at his 70 fsw (21 msw) stop during the mix training dive and spit his regulator out of his mouth.

A second diver was on the scene in seconds, and unable to reinsert the regulator and having a substantial decompression obligation, inflated the divers BCD and sent him to the surface. The diver was picked up immediately by the surface support crew and displayed faint irregular breathing. He was cut out of his equipment, lifted on the boat and placed on oxygen when he became semi-conscious. Emergency evacuation procedures were initiated and the boat left to rendezvous with an ambulance dockside about 50 minutes away. The diver regained full consciousness within about 15 minutes and did not exhibit DCI symptoms. He was evacuated from the hospital to a chamber within a hour and a half. Still not exhibiting symptoms he was treated with a Table 6. The diver has little memory of events following his 90 fsw stop until regaining consciousness at the surface. Apparently his only warning was a 'vague' feeling that something was wrong after switching to O2.— *Reported by Key West Diver Inc.*

Note that following an extensive accident debriefing, Key West Diver Technical Diving Center has devised a simple effective oxygen regulator 'guard' to prevent the unplanned use of oxygen at depth using surgical tubing. The management team believes that neither regulator labeling and/or color coding, or standardized stage bottle placement are sufficient safeguards to prevent these types of incidents. For information on how to construct a guard call 800-873-4837 f: 305.294.7612.

* The title of this report was based on a chapter, Understanding Oxygen: The Good, The Bad, and the Ugly, Mixed Gas Diving, by Tom Mount, Bret Gilliam et al, Watersports Publishing, San Diego, CA 1992.

Evolution of Dive Planning

by Mark Powell

Photo by Trisha Stovel

Plan the dive and dive the plan has long been the mantra employed in all areas of diving. Technical divers, in particular, spend more time planning their dives than many recreational divers. This is due to a number of factors including increased risks, greater depths, high gas usage at depth, increased decompression obligations, increased oxygen toxicity loading, and a host of other reasons. For many recreational divers, dive planning has become a lost art, but technical divers still place a large emphasis on the value of dive planning. Despite this, the methods of dive planning have changed to take advantage of changes in technology and equipment. In this article, we will look at how dive planning for technical divers has evolved, and how we can best make use of modern technology while still maintaining safety. We will consider how understanding the functions of your dive computer can provide additional information to help you dynamically plan your dive.

In the olden days...

In the early days of technical diving, there were no PC planning tools or dive computers suitable for technical dive planning. The only option for planning a dive was to look up a decompression schedule using pre-generated tables. Initially, not even the pre-generated tables were publicly available, and the very earliest technical divers had to use commercial diving tables or work directly with decompression researchers if they wanted to obtain a set of trimix tables. The decompression schedule would be copied onto a dive slate with fixed decompression stops and run times. CNS and OTU loading would be calculated by hand and gas usage would be calculated for each phase of the dive, and the rule of thirds used to add in a safety reserve. The dive would then be executed by following the dive plan run times written on the slate with depth and time being monitored using a bottom timer.

Backup plans would also be prepared just in case the diver goes slightly deeper, stays slightly longer or, in the worst case, goes both deeper and stays longer. With pre-prepared decompression tables, "slightly deeper" was usually taken to mean the next depth increment, which on many tables was 3m or 10ft deeper. "Slightly longer" would be taken to mean anything from 3 to 5 minutes longer. Finally, a backup plan would also be prepared showing the decompression schedule if the diver loses their decompression gas and has to complete their deco using back gas.

With the increased availability of personal computers, it became feasible to generate custom tables using a PC planning tool. This allowed divers to use a number of different gases, decompression models, and conservatism settings. The overall process of planning a dive remained the same, just using a planning tool instead of tables. The planning tool would generate the decompression schedule, CNS and OTU loadings, as well as gas requirements. The only difference would be that the PC planning tool would do the laborious arithmetic required to calculate gas requirements, CNS loading, etc, rather than the diver doing it by hand. When used correctly, these PC planning tools removed the risk of the diver making a silly mathematical error. The computer-generated schedule would then be transferred to a slate just as when the plan is generated by hand. In the water, the dive would be executed in exactly the same way with the diver using their bottom timer to monitor the run times written on the slate.

In time, personal dive computers became available that could handle decompression diving, trimix or rebreathers, but they were still expensive and often unreliable. As a result, it was common to use a written plan on a slate with a computer as a backup in case of going off the plan or in case of an emergency.

This was not an ideal situation as divers would have to spend a significant amount of money on a dive computer without being able to make full use of it. This led to the difficult situation where the diver would have to forego the flexibility offered by the dive computer and stick to a fixed depth and time in order to be able to fall back to their written backup plan in the case of a computer failure. This difficult decision made many divers and agencies question the suitability of dive computers for technical diving.

A New Dawn

However, as computers become more common, reliable, and affordable, this gradually changed. Divers would still use a planning tool to generate a deco schedule to write on their slate just as before. The change was that this schedule was now used as a backup to the computer which became the primary method of running the dive. Despite this, the plan would still primarily be predetermined in terms of a fixed bottom time, in order to still be able to fall back to the written plan. However, the actual ascent time would now be determined by the deco schedule on the computer.

Now computers are much more available and reliable. In addition, the costs have reduced so much that many people have backup computers. The flexibility offered by the computer is in contrast to the rigid nature of tables. Unfortunately, when your backup is based on written tables, you can't make full use of this flexibility. However, when you have a backup computer, suddenly this flexibility comes into its own and this is where significant changes to planning styles started to be adopted.

Photo by Trisha Stovel

This is a real mindset shift for many divers. There is still an impression that we should always use tables or that tables are somehow safer than using a dive computer. In reality, a dive computer gives a much more flexible tool for managing the dive. However, many divers keep the tables mindset even when using a very reliable and flexible planning tool. It is important to understand the features incorporated in your dive computer as they can provide additional information that can be used to manage the situation.

When you have a fixed deco schedule, working out the gas usage for that schedule is relatively straightforward. The disadvantage of having flexibility in the deco schedule is that it now becomes impossible to calculate exactly how much gas will be required in advance. This is where a shift in the approach is required. If we think about the point of gas planning, it is to ensure you don't run out of gas, even in an emergency situation. Specifically, you want enough gas to get yourself and your buddy to the surface, or to the next breathable gas source even in a stressful situation. This is known as minimum gas. You can calculate your minimum gas in advance for your maximum planned depth. This is based on combining the breathing rates of you and your buddy, then doubling this figure to take into account the stress of an out of air emergency. This is then multiplied by the total time involved in dealing with an issue on the bottom combined with the time required to ascend to the first gas switch stop. You can then multiply this by a figure to account for the increased pressure at depth to give the total volume of gas required in litres. Finally, convert this into a bar pressure by dividing by the size of your cylinders. Let's say that after performing this calculation you know that your minimum gas is 70 bar. This means that at any point in the dive, as long as you have at least 70 bar, you know you have enough gas to get to the next source of breathable gas, even if your buddy has a catastrophic gas loss. Once either of you reaches 70 bar, you must start the ascent. Using minimum gas rather than fixed usage gives you the flexibility in back gas planning to match the flexibility in deco schedules provided by the dive computer.

Minimum gas calculations will cover the gas required to get to the first gas switch but what about the gas required for the deco stops? The traditional approach has been to work out exactly what is required and see how much is available to ensure that the amount required, plus a contingency, is less than the amount available. The alternative is to use a planning tool to find the maximum amount of deco that can be done on the gas available, without exceeding the safety reserve. You now know that you can do this amount of deco, and this can be converted to a total time to surface (TTS). Again, you know that this time to surface can be done within the gas available. This means that as long as the total time to surface is less than this maximum amount, you know you have enough gas available.

Putting these two concepts together, the procedure is to first calculate the longest dive that can be done at the target depth within the deco gas limits. This can be used to find the maximum TTS. You then calculate the minimum gas required to get you and your buddy up to your first gas switch. Provided the dive is around the target depth, you just need to monitor your available gas and your time to surface. The actual bottom time becomes less important. The dive is terminated when either of these limits is reached; either the available gas reaches the minimum gas limits or the total TTS reaches the maximum amount.

On the Shearwater computer range, the TTS is shown on the display so that you can instantly relate your current TTS with the maximum TTS that you have calculated. It doesn't matter what depth you have been at or what your total dive time has been. You know that as long as your TTS is less than your predetermined maximum TTS, you have enough gas to complete your decompression.

If you dive with a regular buddy and always use the same size cylinders and the same gas mixtures, then this means that the minimum gas and time to surface will always be the same for each dive at that depth. As a result, you only need to calculate these numbers once for any given dive depth. With a PC planning tool, it is very easy to calculate these two numbers for a range of dive depths. This can be turned into a table in your wet notes that contains all the required information you need for dive planning. With modern dive computers, you don't even need to use a PC planning tool. Your dive computer can do all of the gas calculations for you.

Depth (m)	Min Gas	TTS
45	70	62 mins
50	75	64 mins
55	80	67 mins
60	85	72 mins

Sample dive planning table showing min gas and TTS for a range of depths. Note these are not real numbers and should not be used for dive planning.

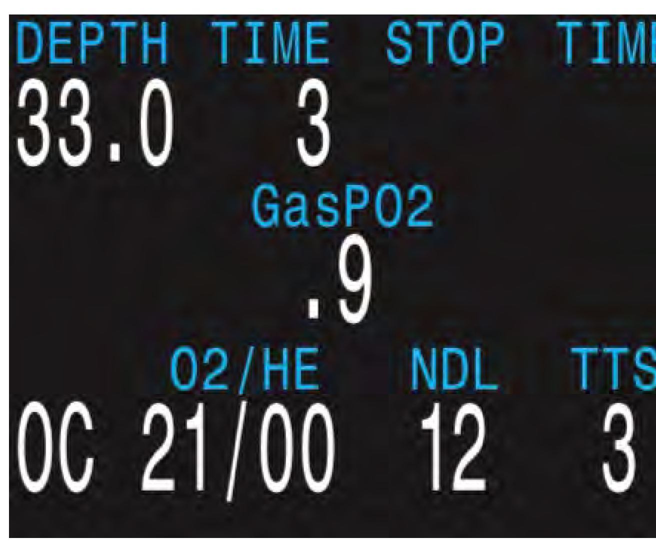
The discussion so far has mainly been concerned with open circuit diving, but CCR diving has progressed along a similar path. Modern rebreathers almost always have a built-in decompression computer integrated into the handset and most divers have a backup computer. However, gas planning is very different on a rebreather compared to open circuit. A CCR has almost unlimited gas and, if nothing goes wrong with the CCR, it is likely to be scrubber duration or CNS limits that will determine the maximum length of the dive. The only time that gas usage becomes an issue is in the case of a bailout where gas availability becomes critical. In reality, it is the bailout scenario that will normally be the limiting factor for most CCR dives. This means that bailout planning will determine the limits for TTS. This is done by using a planning tool to calculate the maximum CCR bottom time that can be done without then exceeding the available bailout gas when the diver bails out at the end of the planned CCR bottom time. The CCR TTS at this point becomes the endpoint of this dive as we know that as long as we stay within this CCR TTS, the corresponding bailout ascent is achievable with the bailout available. For most dives, it will be gas usage, either back gas, deco gas or in the case of CCR, bailout gas, that will determine the limits of the time. Other factors such as CNS should also be considered, but when the dive plan is generated using the PC planning tool or your dive computer, the CNS can be reviewed and, provided it is well within safe limits, can be considered as a secondary consideration to the real limiting factor.

Tech training tends to follow the evolution above with new divers starting with written plans, generated from pre-printed tables or pc planning tools. This ensures that the diver understands the principles behind decompression schedules and gas planning. It also ensures that the diver can manage ascent rates and display the discipline required to follow the dive plan on the computer accurately. They then move on to using dive computers with tables on a slate as a backup before eventually planning using the TTS and minimum gas approach.

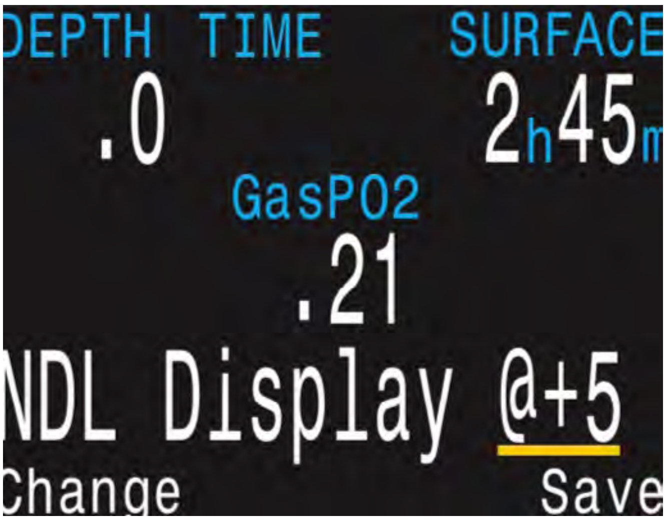
It must be remembered that overhead environment diving also introduces a number of other factors when considering dive planning. For cave and wreck penetration, the minimum gas and time to surface calculations will have to include the time required to exit the overhead environment as well as the time to ascend, and so the planning becomes more complicated. The TTS setting does not include time to exit a wreck or cave, and so cannot be applied as easily in an overhead environment setting.

Real Time Management of Risk

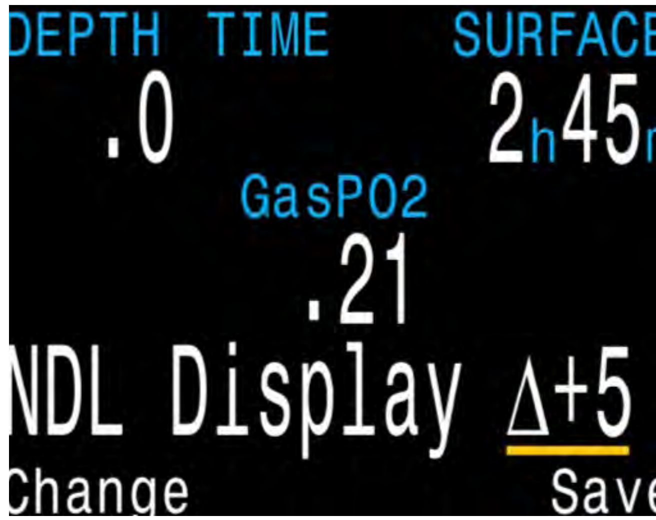
On the Shearwater computer range, the NDL is shown on the display and counts down the time available until it reaches 0. Once the diver goes into deco, this field can be configured to show a number of other pieces of information. Any one of these can be selected to be shown in the NDL space once the NDL reaches zero. Alternatively, all of the following options can be viewed together by stepping through the display options.



The @+5 option is particularly useful. It shows what the TTS will be in 5 minutes, assuming the diver stays at the same depth. This can be used for looking ahead. If you know your maximum TTS, then you can compare this against your current TTS to see if you have reached your limit, but the @+5 setting allows you to look ahead 5 minutes and see what your TTS will be in the future. You can use this to decide whether you have time to look at another piece of the wreck or whether you must turn around and head back to the shot-line. This is particularly important at deeper depths where the rate at which decompression is built up is much faster, and a large amount of deco can be incurred in a relatively short period of time.

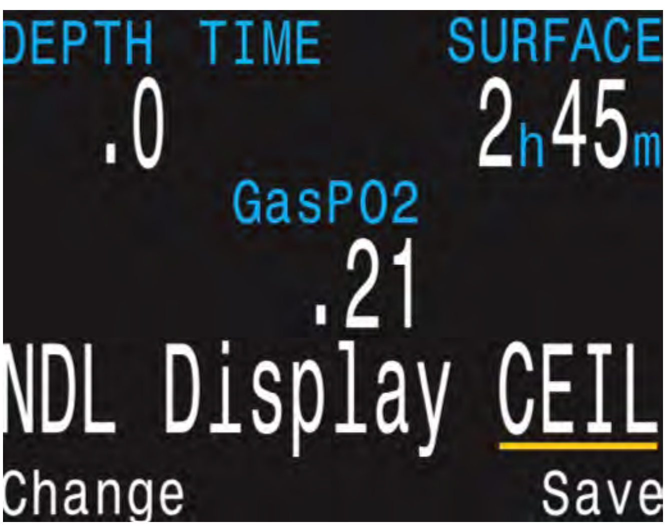


The Δ +5 option shows the difference (the delta or Δ) between your TTS right now and what your TTS will be in 5 minutes. For example, if your TTS is 20 mins and your @+5 is 30 minutes then the Δ +5 would be 10 minutes (30-20=10). In other words, in 5 minutes time, you will have incurred an additional 10 minutes of deco more than you have right now. This could be done manually, but in some situations, it is nice to be able to see the delta without having to constantly make that calculation. The size and magnitude of this figure can also be used to tell the current state of your decompression. If the Δ +5 is positive, this means that you are on-gassing and will have more decompression in 5 minutes than you have right now. If Δ +5 is 0, then you are neither ongassing or offgassing and you will have the same amount of decompression in 5 minutes as you have right now. Finally, if the number is negative then you are offgassing and you will have less decompression in 5 minutes than you have right now. This is particularly useful for multi-level dives. Let's assume you are on a deep reef and you notice that your TTS is approaching your maximum TTS. You ascend a few metres and you notice that your Δ +5 is now +1. This means that you are still incurring additional decompression, although at a much slower rate, and so your TTS will continue to increase. If you come up a few metres more, you can now see that your Δ +5 is zero. This means that you are neither ongassing or offgassing and you can stay at this depth without increasing your TTS. If you ascend slightly shallower and your Δ +5 changes to -1 then you can see that you are now offgassing and you can stay at this depth almost indefinitely as your TTS will slowly reduce.

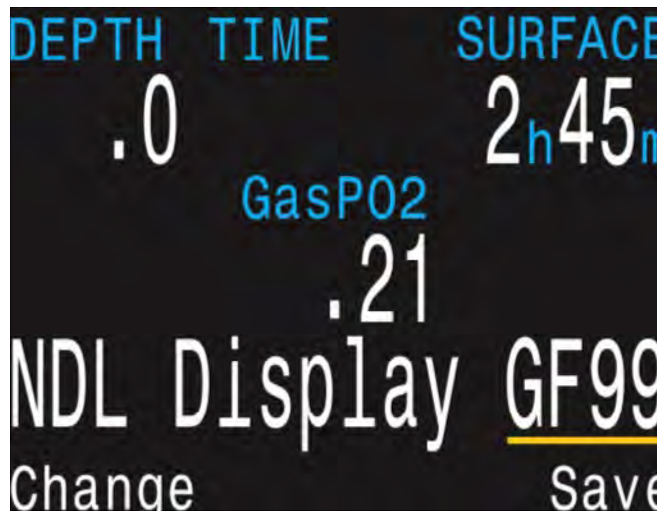


The settings above can be used to proactively manage the dive and can be used on any dive. There are several other options that would primarily be used in an emergency to change some of the dive parameters on the fly.

The CEIL option shows the raw decompression ceiling. Once the diver goes into decompression, they can no longer ascend directly to the surface, and there is a depth at which the supersaturation would exceed the maximum allowed. The decompression ceiling is the exact depth at which this would occur. This is slightly different from the decompression stops shown on the computer as the deco stops are rounded to the nearest 3m increment below the actual decompression ceiling. The actual value of the ceiling will slowly get shallower during the decompression, but the decompression stops will stay at the 3m increment until the ceiling reaches the next 3m increment. At this point, the decompressions stop will jump up to the next 3m increment. By comparing the decompression stop and the CEIL value you can see how much margin for error you have at that stop or how close you are to the end of the decompression stop. If your computer shows a 9m stop and your CEIL is 8.9m then you can see that the ceiling is only slightly above the current decompression stop and so there is very little margin for error in your position in the water column, and you also know that you will be at 9m for some time to come. As the CEIL moves up and gets to 8m then 7m and then 6.5m you know that your decompression stop is coming to an end. This can be useful to know if, for example, you are decompressing on a line at 9m along with a number of other divers. If it is getting crowded on the line at the 9m stop, but you know your CEIL is showing 6.5m then you can move up to 8m or 7m without breaking your ceiling. Your computer will alert you that you are above your decompression stop, and if you stay at that depth, it will give you a MISSED DECO alarm, but you know that despite this you are in fact below your decompression ceiling.



The next setting that it is possible to select in the NDL space is the GF99 setting. This is useful information to know as it shows the current GF, in other words, how close you are to the M-Value which corresponds to a gradient factor of 99. Whether a diver selects his own gradient factor settings or makes the decision to use the default settings, the computer will display the ceiling, decompression stops, as well as the time to surface, based on these gradient factors. If the diver is using 30/80 gradient factors, then during the ascent up to the first stop the GF99 should be approaching 30, as the first stop is calculated as being at the point where the GF is at 30% of the M-Value. At the surface, the GF99 will be 80, as the high GF determines how close the diver is to the M-Value on surfacing so a GF Hi of 80 means the diver should be at 80% of the M-Value as they surface. For intermediate decompression stops, the GF99 will slowly increase from 30 on arrival at each subsequent stop. During each deco stop, the GF99 should slowly decrease as the tissues offgass and the ceiling increases. Once the stop clears and the diver moves up to the next stop, the GF99 will again increase. This allows the diver to "see" the offgassing taking place as it shows that as they offgass, the level of supersaturation is dropping, and they are moving further away from the M-Value.

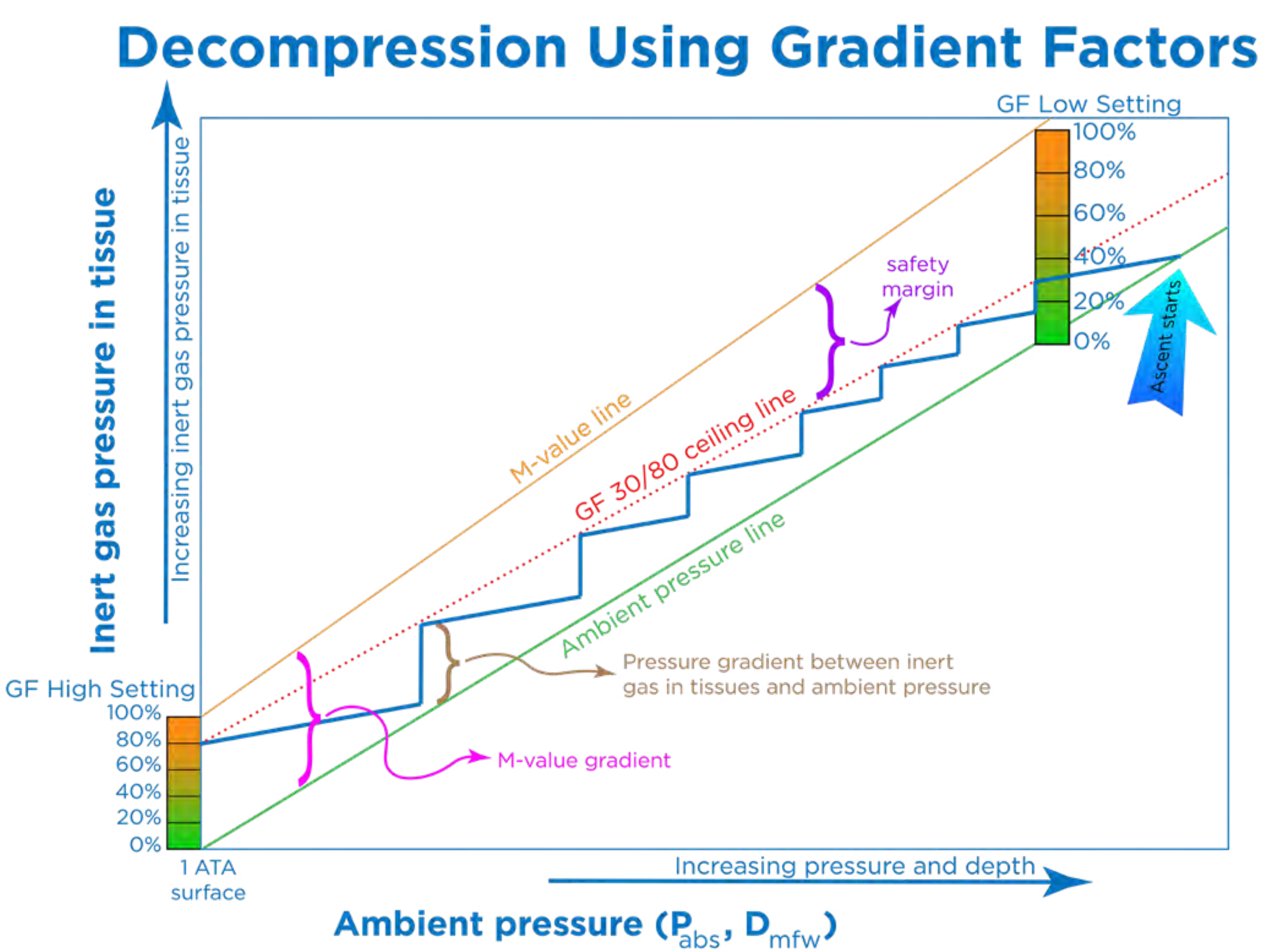


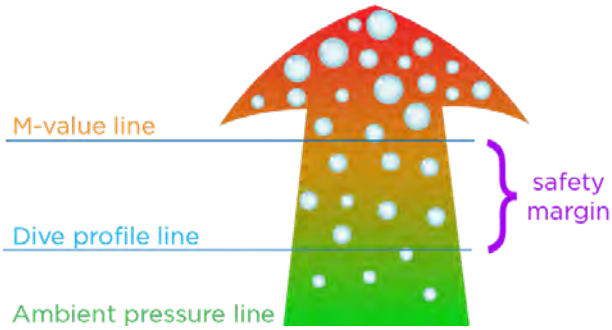
If the GF99 is much lower than 30 on the initial part of the ascent or does not slowly increase on the ascent up to each subsequent stop, then the diver is ascending slower than intended. The TTS shown assumes the diver will be ascending at the prescribed ascent rate. If the diver is ascending slower than the correct ascent rate or stops below the decompression stops, then they are, in effect, lagging behind the calculated decompression schedule. The result of this is that the diver is not offgassing as quickly as the model has assumed, and so the diver will take longer to decompress. In extreme cases, the diver may still be ongassing in some tissues, and the slow ascent may actually increase the decompression requirement. As a result, the actual ascent time may be considerably longer than the calculated TTS. If the diver is using the calculated TTS to manage their dive as described above, this can cause a problem as the gas planning assumed that they would be following the calculated decompression schedule. By causing additional decompression time, they will end up requiring additional gas for this extra time.

If the diver ascends above the deco stop, the computer will give a warning. As we have already seen, you can ascend above this deco stop, but still, stay below your decompression ceiling as shown with the CEIL display. If you ascend even further beyond the CEIL depth, the GF99 can be used to provide some additional information. For example, if the diver has set a GF Lo of 30% and ascends above their initial deco ceiling, the computer will give a warning. The GF99 may still show that they are only at 40% GF which, although it is beyond both their deco stop and deco ceiling, is still well within the M-Value. Similarly, for the later stops, if the diver has set a conservative GF Hi of 70% and ascends above their deco stop, the computer will give a warning. The GF99 may still show that they are at 80% GF which is still well within the M-Value. However, if the GF99 shows more than 100%, the diver is now well over their M-value and is in a much riskier position.

The same goal can partly be achieved in the Dive Settings menu where it is possible to change the high gradient factor during the dive. By changing the high gradient factor from, say 70 to 80, you would reduce the rest of the remaining decompression. Although it is possible to change the high gradient factor in this way, it is not possible to change the low gradient factor, and so the initial stops would be unchanged.

This functionality is not intended to be used on a regular basis, and the diver should stay within the ceilings indicated. However, in an emergency, this functionality may be very helpful. For example, assume that a diver on a decompression dive is running low on gas. Their computer tells them that they have another 5 minutes of decompression to do before they can move up to the next decompression stop where there is more gas available. They could edge up from the current stop to the next stop while watching their GF99 setting. Even though they are breaking their decompression ceiling they can use the GF99 display to show them how close they are getting to their M-Value and can then make an educated decision on what is the more important risk.

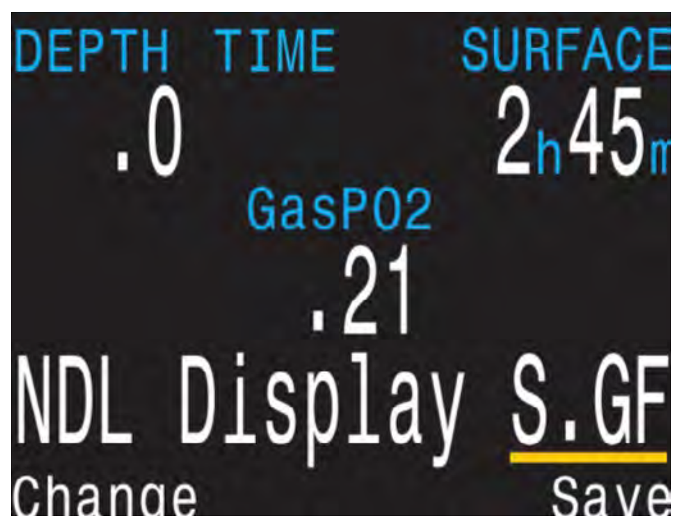




These last few options may seem worrying, or even dangerous, but remember that the stops are determined by the gradient factor settings. If you are using a GF of 70 then you may have a deco stop which would not be present if you had selected a GF of 80. So, missing a deco stop using a 70 GF, but still staying less than 80 on the GF99 display is equivalent to staying within the deco stops on a GF setting of 80%. In fact, you may have deco stops, while the underlying Buhlmann model, which is based on a maximum gradient factor of 99, may indicate that it is within the No Decompression Limit. This is completely normal for the first few minutes of going into deco. If you have your GF settings set to anything less than the maximum value of 99%, then a GF profile will always go into deco before the underlying Buhlmann NDL limit is reached.

The same approach could be adopted with ascending all the way to the surface. In a critical emergency, the diver could edge up towards the surface watching their GF99 display and making sure that they stay close to, but not exceeding, their M-Value. However, this case can be managed more effectively using the Surfacing GF display feature. This is a newer feature and may not be available on your computer unless you have updated the software recently. The Surfacing GF displays the GF that you would get if you were to ascend directly to the surface right now, without doing any stops.

If the SurfGF display shows 50, this means that if you were to ascend to the surface directly, your maximum tissue saturation would be 50% of the M-Value. I.e., well within your M-Value limit with almost no chance of DCS. If your SurfGF shows 150%, this means that a direct ascent to the surface would put you at 150% of your limit, and well over the M-Value limit with a very high chance of DCS. Finally, if your SurfGF shows 99, then a direct ascent to the surface would put you right on your M-Value limit and is equivalent to the NDL limit of a straight Buhlmann model. Interestingly, you can be in deco but still have a SurfGF of less than 99. Remember that the deco stops are based on your selected GFs. If you have the default GF setting of 30/70, then you will start to get deco stops well before you reach the underlying NDL limit. So, if you have 5 minutes of deco shown on your computer but your SurfGF is 90 this means that you have 5 minutes of "GF Deco", but you have not yet reached the NDL of the underlying Buhlmann model. This means that, in an emergency, you could still go straight to the surface without breaking the Buhlmann decompression schedule. This is very different from the situation where you have 15 minutes of deco and your SurfGF display shows 120. In this case, you have "GF Deco" as well as "Buhlmann Deco". If you were to go straight to the surface, you would not only miss the deco stops indicated on the computer but would also end up being over your M-Value on the surface and have a significant risk of DCI.



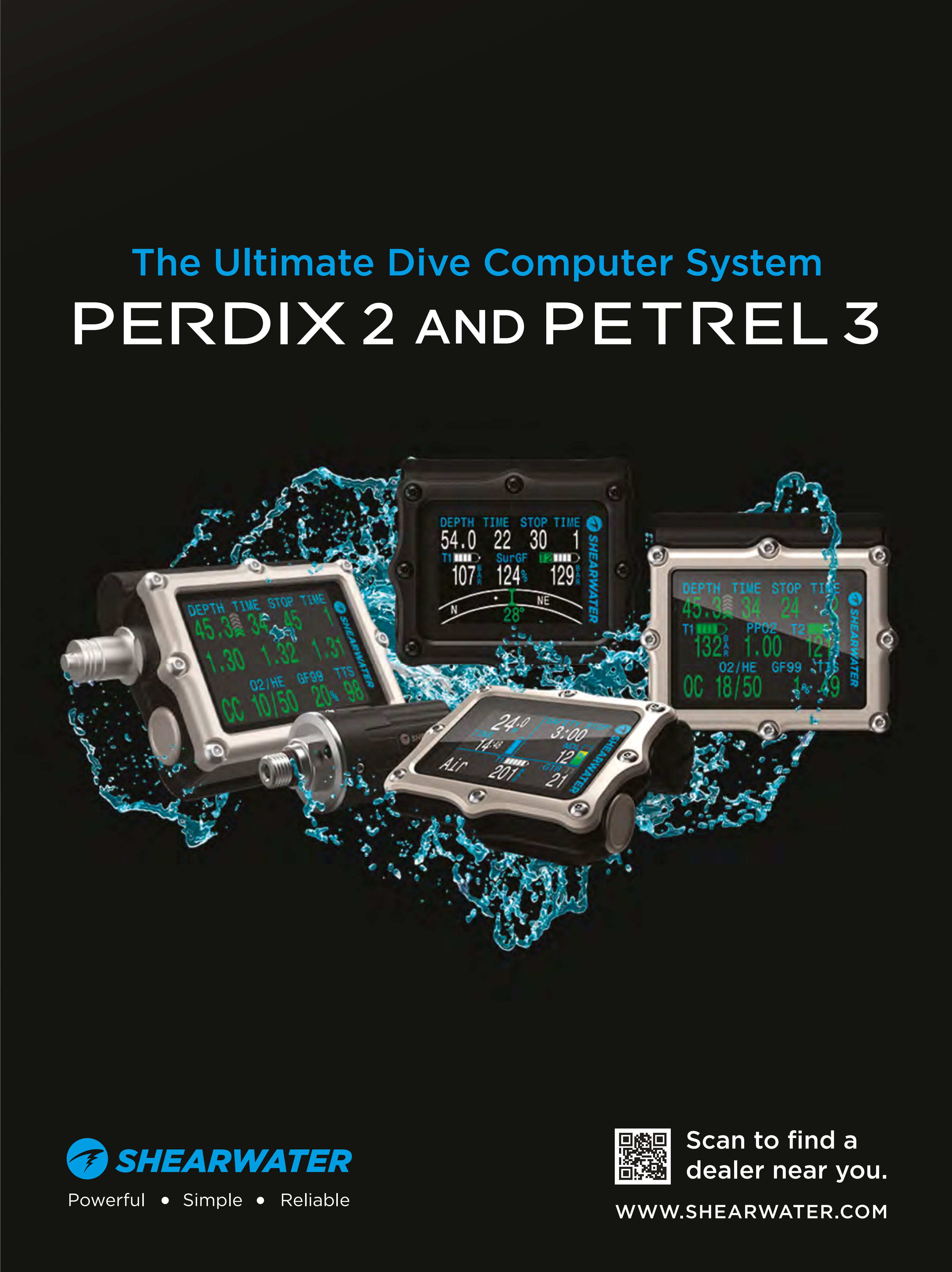
The SurfGF feature can be used at any point of the dive, not just at the start of the ascent. For example, you can track your SurfGF during your ascent and deco. Once your SurfGF drops below 99, you know that from that point onwards if there is an emergency, you could go to the surface and still be within the Buhlmann limits. Equally, you can use it the other way around. After your deco stops have cleared, you can monitor the SurfGF to see your updated SurfGF. One technique that can be used is to have a slightly more aggressive high GF such as 80 or 90 to reduce the mandatory decompression stops but then wait until the SurfGF has dropped to a lower level as a "safety stop".

As the tools available to divers continue to change and improve, it is inevitable that the techniques used must also change to make the most of the available tools. This article is intended to show that, far from removing the need to plan a dive, the sophisticated dive computers available today can help to improve the planning process. They can be used to provide a more realistic and more flexible planning tool. They can also be used to adapt the plan when the situation changes. This is only possible if the diver understands the tools they have at their disposal and practices using them. After reading and digesting the information contained in this article, I would encourage you to make sure you know where to find the various display options on your computer. On your next dive look at the SurfGF value during the dive and watch the relationship between it and the NDL value. During the NDL ascent, look at the GF99 and SurfGF values.

Then on a decompression dive, compare the CEIL and Stop Depth values as well as comparing the CEIL, GF99, and SurfGF values. It is essential that you understand all of the information in this article and practice it before using it to plan your dive or modify your dive plan. Like any tool, you must practice before using them for real. However, a bit of investment in time and practice will give you the ability to manage your ascent in a much more intelligent way than blindly following your computer or a fixed set of deco tables.

Written by Mark Powell

Mark Powell has been diving since 1987 and became an instructor in 1994. In 2002, he set up Dive-Tech, a dedicated technical diving facility. He has been a full-time Diving Instructor since then. He is a TDI Instructor Trainer, and a member of TDI's Global Training Advisor Panel. He is a TDI/SDI International Business Manager and supports Regional Managers and divers across the world. Mark represents TDI on the British Diving Safety Group and the HSE Recreational Diving Industry Committee. He is also a member of the Diver Training and Breathing Apparatus committees at the British Standards Institute. Mark is an author, and his books "Deco for Divers" and "Technical Diving - An Introduction" are both highly recommended readings by a number of the technical diving agencies.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E A S Y

TANKS					
AIR CU. FT.	SERVICE PRESSURE	LITERS	OUTSIDE DIAMETER	HEIGHT	WEIGHT
95	220 bar	12	8.03"	21.85"	47 LBS
120	220 bar	15	8.03"	25.78	55 LBS
140	220 bar	18	8.03"	29.92"	63 LBS
190	300 bar	18	8.03"	31.29"	87 LBS

V4/V10 300 b. — V3/V8 200 b. — V4/V10 200 b.

DIN conversion kits.
Allow conversion of INT yoke type regulators to either 200 or 300 BAR DIN system

nitrox co

*One of the pioneers of dive computing, ORCA Industries launched its now classic EDGE computer in 1983 setting off a revolution in dive instrumentation. After stumbling badly following the introduction of the first air-integrated DC, the Delphi, in 1990, the company was forced into liquidation only to be picked up electronics design manufacturer, Electronic Instrumentation and Technology, Inc. (EIT) of Sterling, Virginia in 1991. Having successfully restructured ORCA and re-engineered its key product lines, EIT unveiled one of the first the first EAN-compatible dive computers, the "***Nitrox Phoenix***" in January, 1993 at the tek.93 conference. Currently, the Phoenix, a single mix DC running EAN 32 (32% O2, 68% N2) is the only EAN-compatible computer on the market.*

The Phoenix Arises

By Paul A. Heinmiller

Ten Delphi dive computers, modified for use with NOAA Nitrox II, i.e. EAN 36, (36% O2, 64% N2) were delivered to NOAA's Undersea Research Center at the University of North Carolina, Wilmington, in October, 1990. The delivery and the subsequent workshop that was held were the culmination of a year-long project to modify the ORCA decompression algorithm for use with enriched air nitrox (EAN), test the resulting dive schedules against generally acceptable values, and produce an EAN-compatible dive computer.

MODIFYING THE ORCA ALGORITHM

Until 1990, the ORCA computational algorithm was limited to air diving. The algorithm uses twelve mathematical compartments with half-times from 5 to 480 minutes. Its limiting compartment pressures, known as "M-Values," are more conservative than Workman's original values for the U.S. Navy tables based on the no-bubble limits established by Spencer with doppler testing in 1976.

By increasing the limiting values, i.e. dividing by the appropriate nitrogen gas fraction, it was possible to modify the algorithm for use with enriched air nitrox. This simple modification would be sufficient if the diver were to saturate on the enriched air mixture prior to the dive and breathe EAN during all surface intervals. Obviously this is not the case. Instead, the diver breathes air while on the surface with a higher fraction of nitrogen than expected by the nitrox-modified algorithm. To account for this the equivalent depth of nitrogen must be substituted. At sea level, i.e. 33 fswa (feet of sea water absolute), the nitrogen partial pressure of air is 26.07 fswa. This is the same nitrogen partial pressure present at 5.33 fswg (gauge pressure) when breathing EAN 36 *(i.e breathing air at the surface is equivalent to breathing EAN 36 at 5.33 fsw).*

This equivalent depth is used by the algorithm whenever the diver is on the surface and assumed to be breathing air instead of the absolute surface pressure. At turn-on initialization, all compartments are assumed to be saturated at this equivalent depth. This has the effect of having the

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reprogramming the future

An Interview With Kevin Gurr, President, Aquatronics, UK

by Michael Menduno

a/c : *You started designing dive computers some time ago.*

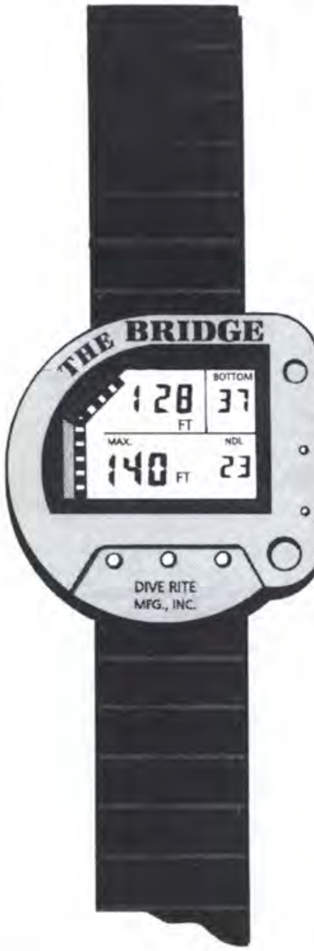
Gurr (G): Six years ago, as more of a feasibility exercise, a couple of friends and I tried to put together a reprogrammable computer. The prevailing attitude of computer manufacturers seemed to be, "Hey, we got a new computer. Throw out your old one and buy the new one." We wanted to offer divers something more. Mechanically it not was very good, to say the least. So we ended up scrapping the original as soon as it was out and producing an improved version, the ACE ProFile.

mputing

*Scheduled for release in the fourth quarter of the year, Dive Rite's "**Bridge**" computer attracted a great deal of attention at both the tek.93 conference and the DEMA trade show earlier this year. To be priced competitively with "high-end" air computers, this unit will provide decompression management and oxygen tolerance information for both air and enriched air diving and should prove to be a useful tool for a wide range of applications.*

Building The Bridge

by Randy C. Bohrer



Developing new electronic instrumentation is often a complex process involving multiple vendors. The Bridge was no exception. Drawing on a wide variety of expertise, the Bridge development and manufacturing team consisted of 8 vendors including; Dive Rite Manufacturing, Seiko-Epsen, , Mitsusu Industries Corp., NEC, Inabata and Co., Underwater Applications Corp., Do Re Mi Software, Hamilton Research Ltd, and Progress Associates, New York City, NY. Considering the size of the vendor team, the complexity and expense of the project is clear.

FEATURE SET

The Bridge offers a feature set similar to other advanced dive computers including a computational algorithm that is valid for deeper dives and extended decompression capability, and dive data recording and playback through a personal computer interface. However its primary uniqueness is its "variable mix capability." To dive the Bridge, the user selects the appropriate oxygen percentage ranging from 21% (air) up to 50% in 1% increments before each dive depending on his or her breathing mix. In addition, the user can change the percentage between dives, allowing different mixtures to be used during the course of a dive day.

Decompression is calculated by a modified 9 compartment Bühlmann model algorithm. The nominal half times are 5, 10, 20, 40, 80, 160, 270, 360, and 480 minutes. This algorithm tracks three more compartments than Uwatec's Aladdin and Monitor computers. The extra compartments in the 5 to 360 minute range provide slightly better resolution while the 480 minute compartment provides some additional safety for repetitive decompression diving.

The algorithm itself is not as interesting as its implementation.. Calculations performed to determine no-decompression limits, decompression stop times, and compartment gas loadings are tedious even for an electronic computer. Most single chip microcomputers are incapable of multiplication or division, and fewer still can perform any high level math. Required math functions are typically implemented in software which requires time and memory; most dive computers on the

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a/c: *You were able to load different decompression algorithms?*

G: Not just algorithms, but options, functions, upgrades that sort of thing. Then a couple of things happened. A friend of mine had an accident with a high pressure gauge line. The hose exploded and split his hand. We decided there must be a better way to monitor high pressure air and so we started playing with air sensors. At about the same time, another friend of mine had a really bad spinal hit for no apparent reason. It was a spinal hit following a first dive of the day to 60 fsw for 30 minutes—just one of those unexplained "numbs-you-up" kind of thing. One of the problems he had was that the medical staff didn't believe his profile when he went for recompression. It gave us the idea that if we could just data log every second of the dive and report exactly what went on—like ascent profile, ascent rate, the whole thing— we could develop better algorithms.

a/c: *That led to Quatek's enriched air computer?*

G: That's right. It was essentially a software upgrade to the ProFile that offered a gas sensor, an optional onboard analyzer, decompression algorithm, and all the data log stuff. You could run virtually any mix you want, change the target PO2s, calculate EADs or ENDs through a window arrangement and four contacts that let you get around the system.

a/c: *What's happened?*

G: Basically the company was forced to close its doors due to financing. In some ways, we were our own worst enemy. We were really good with ideas and putting them into pre-production. We had several large companies interested and everyone wanted to buy them but we were never able to get sufficient backing to put them into full production. Ironically we had our nitrox version running nearly a year before the Enriched Air Workshop in 1992 *(See "technicalDIVER 3.1," 1992)* . After that nitrox just took off.

To order your own Atmospheric Diving System (ADS) call International Hard Suits @ 604.986.5600 or fax 604.984.9138.

Building A Market

The Hard Way

"I hope that the Newtsuit will be one of those tools that is heavily used. In fact, I hope that two things will happen. One is that we'll have some strong competition, because if we don't, it means that the whole idea was duff. If nobody else is interested, it means we're not making any money and there is no market for it.

The second thing that I fervently hope is that sport divers—*serious amateurs*—will become interested in building amateur versions of the Newtsuit. It's not that difficult. I am planning to publish a book in the not-too-distant future that will show how a lot of it's done based upon 30-odd years of experience. As you can imagine, my board of directors thinks it's a terrible idea and that we should keep it all to ourselves, but I learned many years ago that if you have what amounts to a serious breakthrough technology, you should share it. That's the only way you're going to get to see what it finally becomes. If you cloister it or you hold it too tightly, it just disappears."

Phil Nuytten, International Hard Suits,

tek Conference Interview, 1993

Phoenix continued from p.26

diver begin the dive series with apparent "residual" nitrogen. The computer wakes up saturated at 5.33 fswg pressure relative to the enriched air diving environment.

MODEL TESTING

The modified ORCA algorithm was applied to many different dive profiles and the results were checked against Dr. R.W. Bill Hamilton's DCAP model under a separate NOAA contract. The dives tested included single square no-stop dives from 30 to 130 fsw (9-40 msw), square decompression dives, and square repetitive dives at 40, 60, and 100 fsw (12, 18, 30 msw). Typical working dive profiles supplied by the NOAA NURC group were also run through the algorithm and compared to DECAP results. In a separate report to NOAA, Hamilton endorsed the ORCA EAN algorithm and recommended a period of monitored field evaluation to confirm its validity further.

ORCA created a special version of its Delphi software to implement the algorithm. The Delphi was originally chosen because its program resided in Electrically Programmable Read-Only Memory (EPROM) and was easy to reprogram for nitrox use. The Delphi also included a 35 hour dive profile recorder, considered important for dive control and decompression model feedback.

NEXT GENERATION

The one day Nitrox Computer Workshop at UNCW was well attended by scientific divers and diving safety officers from NOAA, UNCW and other research institutions. In open discussion, the group recommended that future enriched air nitrox computers incorporate oxygen toxicity limits if possible. There were also discussions about the need for more powerful dive computers. This second generation would allow a diver to select a mix before a dive, change mixes between or during dives, and collect scientific data in internal memory.

In early 1991, following the NOAA workshop, the EAN user community was surveyed and a marketing decision was made to limit the distribution of the EAN computers to the scientific community. Before the end of the year, ORCA Industries was out of business. Within three months the ORCA

had our nitrox version running nearly a year before the Enriched Air Workshop in 1992 *(See "technicalDIVER 3.1," 1992)*. After that nitrox just took off.

a/c: *In some sense, you taken the approach of the PC industry; create a standard hardware platform that can run different software packages. Is that the future of dive computers?*

G: I believe there's a need for it, especially with at least two major navies looking at different approaches to decompression. Today, there's no real reason why we can't have a complete electronics system that supports the diver incorporating decompression management, gas sensing, communications, and diver positioning. The technology is here now. The problem is that the dive computer industry is leagues behind the rest of the electronics industry, as far as that goes, because the mass market is basic air diving. The good news is that air divers are becoming more educated. They're starting to see communications as viable, they'd like to see exactly where they are on the planet and GPS (global positioning systems) helps them do it on the surface—why can't it be done below? The answer is it can. It just needs someone to help fund it; to put cash on the line.

a/c: *What do you think of the new wireless high pressure systems that have just hit the market.*

G: I think that wireless systems are more of a gimmick than anything in some ways. The important thing is the gas consumption information.

product line was revived by one of ORCA's contract manufacturers , Electronic Instrumentation and Technology, Inc. (EIT) which had designed and manufactured ORCA's Marathon computer. The Delphi was completely re-engineered in the new Phoenix dive computer, which was released in June, 1992. By the end of the year, the ORCA Division of EIT released a nitrox version of the Phoenix to qualified divers.

ENTER THE PHOENIX

The nitrox-compatible Phoenix incorporates all the modifications of the earlier Delphi, but added the CNS oxygen toxicity limitations recommended by the UNCW Workshop. Instead of NOAA Nitrox II the unit is programmed for use with EAN 32 (32% O2, 68% N2). EAN 32 is presently the most readily available mix other than air and boasts a deeper working range. In its current configuration, the Phoenix can be used with enriched air mixes with less than 68% nitrogen in the same way that a standard air computer can be used with EAN but it cannot take advantage of the full performance of these mixes. The nitrox Phoenix has a maximum operating depth of 132 fsw (40 msw) based on a maximum oxygen partial pressure of 1.6 atm of EAN 32 at that depth.

The nitrox unit is packaged to differentiate it from the standard air Phoenix, so that it is difficult or impossible to use it with air by mistake. The boot of the Nitrox Phoenix is green with yellow lettering, compared to the black and white of the standard model. It is clearly marked, "For Use with EAN 32 Only." The case inside the boot is also green, and marked with warnings. In addition, the software displays the nitrogen percentage on start up for verification. Nitrox Phoenix is available from the ORCA Division of EIT through ORCA dealers who are certified ANDI or IAND Nitrox facilities. The suggested retail price is $899, while the standard air model goes for $699.

Longer, safer bottom times is the reason most sport divers have pursued the use of enriched air. There now exists an instrument which will allow sport divers to intelligently maximize their advantage.

Paul Heinmiller is the Director of Technology at ORCA Division of EIT and a long time contributor to aquaCorps Journal. *He can be contacted at:*
ORCA/EIT, 45625 Willow Pond Plaza, Sterling, VA 20164, f: 703-478-0815.

depending on the type of dive you're doing and your configuration, and have the computer give you your gas time back in minutes. Or how about look ahead ability; to be able to input the dive that you're planning to do and and have the computer tell you whether you can make it with your reserve intact.

a/c: *Isn't the real problem with mix being able to interface with the computer, being able to tell it, "I'm at my oxygen stop and I've just switched?" Have you looked at user interfaces?*

G: We have. Mechanically there are ways to do it, but most of them are expensive. We've been working on a solution for the last year and have something that I think will work but I'm not going to tell you how we do it. I think the solution is around the corner. It's not that difficult. Eventually however, I think user interfaces are going to go to voice synthesis and recognition systems. Not only could the system talk to you, but you should be able to key-word back and say things like, "Switch now". Technologically, there's no reason why that can't happen. It's being done now in fighter planes and with full face masks and communications.

a/c: *That would solve the interface problem. Are you familiar with the "Dive Talker" computer?*

G: A funny story. When it was first out launched at DEMA, I tried it and said to the guy, "It's a woman's voice." And he said, "Yeah, that was my wife." I said, "I dive to get away from my wife." He said to me, "Well, I never thought of that."

Bridge continued from p. 27

market require several seconds to perform the high level math calculations inherent in an algorithm. As a result, the information presented is slightly "outdated." The Bridge combines a clever selection of model parameters with software techniques that allow the necessary calculations to be completed almost instantaneously without sacrificing mathematical precision. This particular refinement is small as far as the user is concerned, but it frees up the microprocessor and memory to work on other item such as oxygen tolerance calculations.

OXYGEN TOLERANCE MANAGEMENT

Though for most sport diving applications, oxygen tolerance is generally not an issue, it is extremely important in enriched air diving. The onset of oxygen toxicity symptoms vary substantially and can result in convulsion and drowning. As a result, limits have been established to help manage the diver's exposure.

In developing an oxygen tolerance model for the Bridge, we began by reviewing the published approaches to the problem. The simple "square interpolation" method that was reported by Kenyon and Hamilton was finally selected and is used to calculate an index representing the level oxygen exposure. This method is also used by the International Association of Nitrox and technical Divers (IANTD) in the training programs. The NOAA pressure-time limit table was selected as the reference for oxygen limit calculations, although other limits can be used with the general procedure.

This method involves calculating the fraction (or percentage) of the NOAA time limit used during each level of the dive. This fraction is determined by dividing the actual time spent at a particular PO2 by the NOAA time limit for that PO2. These fractions are summed in an index variable called the Oxygen Limit Index, or OLI. When the OLI reaches 1.0, or 100%, the diver has reached the oxygen exposure limit. The Bridge performs these calculations once each minute, using the maximum PO2 attained during the one minute period.

None of the existing published approaches dealt adequately for recovery from an oxygen exposure. As a result, a new approach was developed for use in the Bridge. In this approach, recovery occurs when the PO2 is less than 0.5 ATA, for example when the diver is at the surface or is breathing air at depth of less than 45 feet, or NOAA Nitrox I (32% O2, 68% N2) at a depth of less than 18 feet. The recovery equation is exponential with a half time of about 1 1/2 hours. Therefore the OLI becomes one half its original value after 1 1/2 hours, or one tenth in five hours, and nominally zero in 9 hours. It is important to note that, like a decompression algorithm, the information given by the model is not a guarantee of safety; it only indicates the diver's relative position on a theoretical limit scale. What's more is that there is considerable more uncertainty in predicting oxygen tolerance than corresponding DCI predictions. The actual values obtained from this model are in line with what is acceptable in practice for single dives, and for hyperbaric oxygen treatments. The model also limits pulmonary or whole body toxicity exposures, though this is rarely an issue in self-contained diving.

In order to communicate oxygen information to the diver, the Bridge incorporates a bar graph and audible warnings to indicate relative oxygen exposure. The bar graph will increase in length whenever the diver is exposed to an oxygen partial pressure in excess of 0.59 ATM. When the exposure is less than this value, for example while at the surface or in certain decompression scenarios, recovery occurs and the bar graph decreases in length. An audible and continuous warning sounds when limit is exceeded.

An electrical engineer and mix diving instructor, Randy Bohrer is the president of Underwater Applications Corporation which integrates and distributes specialty dive equipment. The lead software contractor for the Bridge, he can be contacted at: UAC,427-3 Amhearst St., Suite 345, Nashua, NH 03063, f: 508.433.6586.

reprogramming

Actually, a number of years ago, a scientific institution over here had done a lot of work on voice synthesis, key words, that kind of stuff. They had a really good system and they were looking to license it. At the time, we were going to buy the technology and the ideas, but the market wasn't great for it. It still isn't ready for voice synthesis now, not quite.

a/c: *What is the future for your new company?*

G: New dive computers will live again. Our goal is to develop an integrated diving information system. Whether we get the backing is another matter but it's the way the technology has to go. Three years ago the timing was wrong. Now all the pieces seem to be falling in place.

Kevin Gurr is the President of Aquatronics Ltd. and is actively involved in teaching mix diving. He can be contacted at Aquatronics, Unit C11, Acre Business Park, Reading, Berkshire, RG2 O8A, UK, f: 635.874.188.

Huggins On EDGE

An Interview with Karl Huggins
by Michael Menduno

a/c: *You were one of the developers of "The EDGE." Did you foresee* that DCs would become such a broad-based tool?

H: There were some people who believed everyone would have a computer. From my perspective, I saw it as more of a high-end tool for people who were doing multilevel diving. It would give them the ability to continuously calculate their decompression in comparison to the table-based multilevel diving that was being done at the time.

a/c: *What was your involvement?*

H: What I did was to take a look at the recommended limits that Spencer, Bassett and Pulmonis had published on the basis of doppler studies and implemented them in the computer. One of the things that I was adamant about was testing to make sure the algorithms weren't way off-base with respect to multilevel diving.

a/c: *No one had applied the algorithm to multilevel profiles.*

H: Not in a rigid, scientific type of study. There were a lot of people in the Caribbean "stepping up" the tables or reading them sidewise. In fact, tables were being used in a way they were never designed for and in some cases the profiles people were doing were probably violating the underlying algorithm. I was concerned about it. That was in the days when I thought the models meant something.

a/c: *How do you view models now?*

H: Models are basically an approximation to come up with a low-risk profile. All of them carry a certain degree of risk. They're not written in stone and there are a lot of day-to-day physiological factors that simply cannot be programmed into a computer.

a/c: *What is your view of the trend towards statistical-based approaches such as maximum likelihood analysis.*

H: I see it as a trend, but there needs to be a caution with the acceptance of any type of algorithm. For example, if you look at Haldanian-based algorithms, you can design something that will work real well within a certain depth and time envelope. However, if you take the same algorithm outside of that envelope, it may fall apart. When you're looking at the statistical models, you've got to realize that their predictions are based on a series of historical data. The data is used to come up with a best fit—the best model to predict what occurred. As long as your diving fits the data that was used to generate the model, then you'll have a relatively good fit. If you move outside that area, then it may not be as good of a fit in terms of prediction.

a/c: *How did you approach that problem with the EDGE?*

H: The Edge was designed for people who were doing multilevel profiles. At that time, a typical profile might involve going deep for a short period of time, ascending and spend most of the remaining time at shallow depths. That's how we geared our doppler testing; a deep multilevel dive at the beginning of the day, short-surface interval and then a shallow dive. A typical two-tank Caribbean dive.

a/c: *How many test dives did you do?*

H: It depends on how you want to count dives. If you look at the entire series as a dive series, then you could say that we did 12 dives because we had 12 different series. If you wanted to look at each one of the dives as an individual entity, then we had 119-person-dives.

a/c: *In your mind what have been the major innovations in dive computers since the EDGE?*

H: In terms of progression, I think there have been four major things. The first was probably ascent-rate warnings which I feel has been a very important feature. Secondly was miniaturization. Once there's a market you can invest in the miniaturization techniques. The third innovation was the ability to record the profiles and dump them back out to the user in order to be able to get an idea of what the actual profile was like. The fourth was being able to sit down communicate back and forth on a PC and be able to change various variables with the unit.

a/c: *How about the next generation?*

H: I'd like to see the ability to stick in safety factors. The one thing that I'm still concerned about with regard to dive computing is the amount of testing done. I don't know if there is any dive computer manufacturer out there— *let me restate that and put this it bold letters—* "**I challenge any of dive computer vendors**

to offer their algorithm for public inspection, and produce the the actual test results that were carried out on the algorithm." What has happened is that companies have taken an algorithm, say the Bühlmann algorithm, and they've said, "Buehlman has tested this model. We're going to tweak it and make it a little bit more conservative, stick it in our computer and say, "OK, the testing associated with this computer can be traced back to Buehlman."

a/c: *By default, the algorithm is "tested."*

H: Exactly. *And they haven't been!* Because of that, I encourage people *not to test* the algorithm by pushing it to the outside envelope. I encourage them to back off. The real problem is that we don't really know how the general diving population are using their computers— the profiles they're diving. What's more is that is we have no denominator in any of our calculations. Whether we're trying to predict diving safety or anything else; we don't know what dives are being done. There's a lot of hand-waving being done to come up with figures.

I think there should be a large effort on the part of the manufacturers to support doppler or look at trying to set up a system like that proposed at the UHMS workshop on table validation *("Validation of decompression Tables," Undersea and Hyperbaric Medical Society, 74(VAL)1-1-88, 1989)*. If we can start getting good profile information out of the field, then we could get a handle on the problem. I look at dive computers as an information-gathering tool.

a/c: *Switching subjects a little, what do you think about the new desktop decompression packages that have just come on the market?*

H: It boils back to something that was said to me by Ed Thalmann of the US Navy almost 9 years ago. I took offense at it at the time but over the years have gradually come to realize was a legitimate statement. I was presenting a paper at a UHMS meeting on computer-generated emergency exit tables for hyperbaric tenders. Thalmann came up, looked at it, and basically said, "Any idiot with a computer can create a set of tables." After my ears stopped burning a year or so later, I started thinking about it. It's true. Anybody who has a simple exponential equation and a computer can create a set of tables. You can do it with a spreadsheet if you want.

a/c: *We have an article planned in an upcoming issue telling our readers exactly how to do it.*

H: The exactness of the numbers can be intoxicating. But there is a big difference between precision and accuracy. The concern I have with the computers, whether it be underwater computers or desktop software, is that all they do is crank numbers through a simple mathematical equation. Unless you have some sort of data to back up what you're doing, you're just sort of shooting out in the dark and don't know what's going to be happening. You're not diving the original algorithm, you're testing the particular variation because you've had to make assumptions to create this new set of tables.

a/c: *What advice would you offer to people who are considering buying these programs?*

H: Get as much information on the history of the specific algorithm and how it was tested. And don't be surprised if it's tough. I've been trying for years to get a handle on the algorithms being used and the testing that's been done on them.

Karl Huggins is recognized as one of the pioneers of modern dive computers and doppler monitoring. Currently the Program Director at Catalina Hyperbarics Chamber, he can be contacted at PO Box 398, Avalon, CA 90704, f:310.510.1364.

a/c

Balance Is Everything

I want to complement you on the thoughtful, well written, and, best of all, BALANCED presentation on the controversial topics that you and your staff address. I appreciate your efforts to provide, not only the most technically accurate and up to date information, but also to put the information into a prospective that is appropriate for technical rather than recreational divers. I disagree with the attitude of editorials I have read in recreational magazines such as "Skin Diver", in which editors stick their heads in the sand and from that illustrious vantage point proceed to dictate policy on all aspects of diving. Ignorance, selective or otherwise does not promote safety. Quite the contrary, the more informed, trained, and skilled an individual is, the less likely that they will hurt themselves or others.

Hank Ellison
Downers Grove, IL

Information Access

The technical diving debate rages on in the UK as you are no doubt aware. However, I sometimes feel the pros and cons are misunderstood by both sides. I get the impression aquaCorps' contributors are concerned with advancing scientific and technical barriers, making dive sites accessible and improving safety in the process. This objective is commendable and long may it continue.

The diving organisations in the UK are reluctant to implement technical advances for the "diving public." On the face of it this is detrimental to diving. I have been a Diving Officer of a BSAC branch with a 100 members ranging from novice divers to long standing experienced divers who regularly carry out 50 msw plus dives on air. From where I stand, technical diving will improve "advanced" diving. The BSAC is doing its experienced members a disservice by its reluctance to promote technical diving to this group.

Tim Cashman
Exeter, UK

Tubular Dude

We have talked to many people about the problems encountered when mixing enriched air and other mixes in T and K cylinders. The gas has a tendency to stratify in layers and the tanks must be rolled for several hours to obtain a mix. The only other option is to let the tanks sit for 24-36 hours before analyzing.

We have developed a stainless steel tube which can be inserted into a cylinder. The tube is crimped at the lower end and screws into the valve. We have drilled holes in the length of the tube. As oxygen, air or other gases are introduced into the cylinder, the gas sprays out the holes allowing an even mix to be obtained immediately. This same principle could be used with an ordinary scuba cylinder by coupling the stainless steel tube onto the siphon tube of the valve.

We are happy to share this device with the community. If any of your readers are interested they should contact us.

Wayne McCall, Keller Mccall, Bob Kinder
250 Mt Springs Rd
West Union, SC 29696

Maintenance Job

I wanted to let you know of a recent experience that really opened my eyes to the importance of properly operating equipment. I recently attended a fantastic regulator repair program offered by Diving Technologies, Davies, FL. When I disassembled my Poisedon regulator for examination and maintenance, I was shocked to find that not only was the regulator out of adjustment, but that several internal parts were damaged and needed replacement. The regulator is only 8 months old.

The demands of high tech diving place a high premium on having properly performing life support equipment at depth. I can't help but wonder what my responsibilities should have been in establishing a regular prevention/ maintenance program to avoid this type of problem.

Andy Mrozinski
Miami, FL

Underground Happiness

I am a HAPPY cave diver. Mike Madden and I did a double tandem scooter dive with 104s and double stage bottles in *Nohoch Nah Chich*. Our plan was to scooter 10,000 feet back from the main entrance to the "Pablo Diaz" line, that I installed last September during the 1992 NoHoch Project.

Our goal was to explore a enormous pit discovered by Madden and Bill Main that appeared to reach 100 feet in depth or more. We were in "awe" as *NoHoch* averages 23 feet in depth and the deepest anyone has seen in the system is 65 feet.

We dropped our first scooter at *Dinnerhole* which is 4700 feet back. We then switched scooters and stages and motored another 5000 feet to the "jump" where the new line begins. Mike told me that there was one tight restriction to negotiate on the way to the pit. He was right. We arrived at the room and saw where the line ended. I swam out over the hole and nearly died and went to heaven. We were looking at at least 150 foot depths. The place reminded me of the Cube Room in *Sally Ward Spring*, crystal clear water with a blue tint and huge pure white boulders. I was ready to "sky dive" down.

Mike tied off and we swam over the edge and began our descent. As we floated down I was "screaming" through my regulator like a kid. We hit a hundred and the thing was still going. I was stoked. We held the dive to 214 fsw though there still was depth to run. MAGNIFICENT. The dive ranked up there as one of my best and favorites. We've decided to call it, *The Blue Abyss*. Green side up, check your six and MAINTAIN.

Steve Gerrard
Playa Del Carmen, QROO, Mexico

Lifetime Members

Glen Armentor
John Britz
James Brown
Lou Cook
Norman Cooter
John Cordingley

Samy Elashmawy
Lalo Fiorelli
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Hardwin Mead
Blaine Merrill
Douglas Roberts
Thomas Shultz
Brian Skerry
Peter Storm
Michael & Ruth Yasky
John Wall

corps space

Priced at $150 (US), the SEGA Virtual Reality Headset is not configured for underwater applications.

Yet. *Given that 'wearable' 386's are just now hitting the streets, we may not have to wait for long. Water sports anyone?*

Do you have information to share with other readers?
Communicate: a/c, PO Box 4243, Key West, FL 33041, f: 305.293.0729.

Ed Betts, President., ANDI and Tom Mount, President. IANTD present an air quality standard at tek.93 with the help of Richard Nordstrom, Dive Comm and instructor Frans Vandermolen who facilitated the agreement.

Finally An Air Quality Specification.

Well almost...

By Cathie Cush

mix watch mix watch mix watch

The two bodies involved in enriched air nitrox (EAN) signed off on specifications for oxygen-compatible air. But instead of clearing the air, the specs sparked new debates. Are they too strict? Are they strict enough? Will mainstream dive shops be able to meet them? Or will they blow themselves up trying?

At tek.93 in January, representatives from American Nitrox Divers Inc. (ANDI) and the International Association of Nitrox and Technical Divers (IANTD) agreed that compressed air to be used with oxygen (O_2) should contain no more than 0.1 mg/m^3 of condensed hydrocarbons and no more than 2 ppm carbon monoxide (CO). Carbon dioxide (500 ppm) and methane (25 ppm) levels are consistent with Compressed Gas Association standards for Level E air. The air may be generated by an oil-less, oil-free or oil-lubricated compressor. Each agency requires its facilities to participate in quarterly gas analysis.

"Gas analysis confirms that primary gases meet commodity specifications and that they are free of contaminants. Periodic gas sampling is also utilized to confirm the effectiveness of filtration systems and to identify requirements for both planned and corrective maintenance on compressors, storage systems or filters," explains Lt. Cmdr. Paul Morson, special advisor to the Experimental Diving Unit at Canada's Defense and Civil Institute of Environmental Medicine (DCIEM). "We are concerned that primary gases—oxygen, nitrogen and helium—are present in known quantities, as these percentages are employed in decompression algorithms. We are further concerned that contaminants are not toxic and do not additionally lead to engineering failure, such as corrosion or flammability."

Condensed hydrocarbons are a potential source of fuel for fire or explosion in highly volatile high-pressure oxygen environments. Rapid compression, friction and particle impact all could ignite a fire in such an environment.

Upping the ante

The agreed-upon specifications represent compromises on both sides. Until recently, ANDI maintained that only air from oil-less or oil-free compressors was satisfactory. New filtration technology motivated the change in position. Before January IANTD didn't have a formal specification for oxygen-compatible air, although operators generally pumped air with less than 0.2 mg/m^3 of condensed hydrocarbons, according to IANTD vice president Capt. Billy Deans.

"Empirical data has shown that to be more than adequate for use with 100-percent oxygen," says Deans. "Nobody can test to lower levels than that unless you're willing to pay big bucks."

"Testing is available to meet the new specification, but I don't have a price yet," says Mike Casey, who handles lab services for Lawrence Factor, a Hialeah, Fla., company that provides high-pressure compressors, filtration and purification systems, and breathing gas testing for both the military and the private sector.

Estimates as to the cost of meeting the specifications vary greatly. According to Casey, "the difference in initial cost might be $500, plus an additional $500 a year. Those are big numbers for a dive shop."

"If you're using an oil-lubricated compressor, it will probably cost $2,000-$3,000 to change over," says Ed Betts, ANDI founder and president. "If you're using a oil-free compressor, it's probably not more than $1,500, and maybe nothing." Betts estimates that analysis will cost approximately $75 per quarter.

"This poker game has an ante," Betts continues. "If you don't have the ante, get your ass out of the chair and watch. If you want to play, put up the ante and sit down."

"This may be overkill," observes Tom Mount, IANTD president. "It's beyond what NOAA and the navy do.

According to Glenn Butler, CEO of Life Support Technologies, Inc., the condensed hydrocarbon spec reflects the minimum detection value of oil and reflects existing filtration technology.

"If you can detect oil, that's reason for cleaning your system," Butler says. "All the documentation to date supports that you need oil-free air.

"The overall program is going to cost more money," he says. "But the guys who are marginal are going to have accidents. There's a tendency to want to short-cut based on economic greed, and that's irresponsible."

Casey doesn't believe that the standard is "way out of line. I would love to see it at that. But I don't think it has to be that restrictive if the system is maintained properly." However, he adds, "the sport diving community isn't as good on maintenance as the technical operators. They're not as thorough, they don't keep records. They're going to be lax, and there are going to be a lot of problems."

The 0.1 mg/m^3 spec for condensed hydrocarbons "is fine, but it may be lower than necessary," says J. Morgan Wells, Ph.D., director of the National Oceanic and Atmospheric Administration's (NOAA) Experimental Diving Unit.

Double jeopardy

Cost isn't the only concern. The specifications have a lot to do with liability. While some say that the agreed-upon limits will protect gas purveyors, others fear that operators are placing themselves in legal jeopardy.

"The sport and technical diving communities aren't inventing all this stuff," says Butler. "For liability reasons, we can't do this much differently from the balance of the industry."

Morson notes that if a dive accident occurs, one question that will arise is, "Did you meet or exceed the known standard? [Breathing gas] standards already exist in commercial, industrial, government and military arenas." As providers of a commodity product, dive shops are responsible for the quality of that gas, Morson adds. "If you're in the game, you're liable."

"I agree that this [specification] is more defensible, closer to existing standards," adds Casey.

Wells offers another perspective. He is particularly concerned about the 2 ppm limit on CO. The U.S. Navy allows up to 20 ppm; more stringent U.S. Fed Spec BB-A-1034 limits CO to 10 ppm.

"The 10 ppm figure is so very low that making it any lower is not going to make it any safer, but it makes it more likely that a lot of dispensers are going to flunk the test," Wells predicts. He envisions an accident scenario in which later gas analysis shows a CO level of 8 ppm.

"Now eight happens to be perfectly safe, but it violates this standard. If a sharp lawyer gets a hold of that information," Wells notes, it could mean trouble, even if the CO level is not relevant to the case. "The 2 ppm spec is unnecessarily low without justification. If we have to meet these specs, we better make them reasonable."

The 2 ppm figure reflects the Canadian Forces Standard for mixed gas for divers. It is based on 1/25 of the Threshold Limit Value–Time-Weighted Average (TLV–TWA) documented by the American Conference of Government Industrial Hygienists (ACGIH). The ACGIH Threshold Limit Value for CO is 50 ppm at the surface.

"That's the current level for individual exposure for eight hours," Wells says.

CGA's Level E air, with its 10 ppm CO limit, Morson points out, is only verified to 130 feet. "What happens when you go to 190, or 400 feet on trimix?" he asks. Such increased partial pressures multiply the toxic effects of the contaminant. The effects of carbon monoxide exposure are cumulative unless the PCO is lower than PO_2 values, he notes. Maximum short-term exposure to CO (15 minutes in 24 hours) is 400 ppm.

"Air is used deeper than enriched air," Wells counters. "Breathing enriched air protects you against carbon monoxide anyway."

Physiologically, CO acts as a function of its proportion to oxygen in a mix. Most CO threshold limit values are based on a background of air at 1 atm. When a mix containing both CO and O_2 is compressed, the ratio of the two gases does not change, making it unnecessary to establish a lower limit for CO at depth.

Missing measures?

The agencies agreed that gaseous hydrocarbons (reference methane) should be limited

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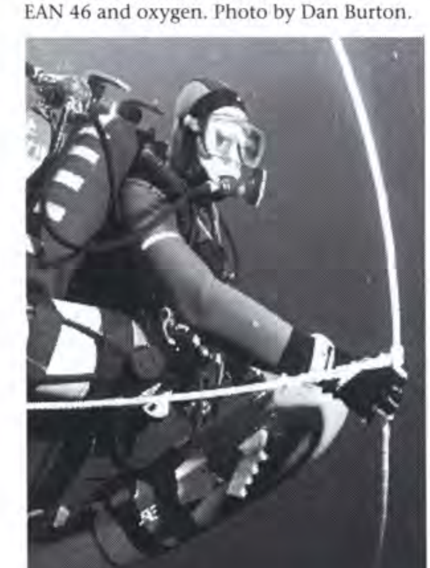
Trimix Report

by Michael Menduno

Capt. Billy Deans and Jim King following a 20 minute exploration dive on the *USS Fred T. Berry* at 378 fsw (116 msw) using trimix 10/60, intermediate mixes; air, EAN 30, EAN 46 and oxygen. Photo by Dan Burton.



Though trimix is being used successfully by small groups of divers in the U.K., Mexico, France, and Switzerland, most of the current work is being done in America. To date, conservatively 1500-2000 open circuit trimix dives have been conducted in the U.S. since 1987 by divers from the wreck, cave and scientific diving communities. Depths range from about 150-870 fsw (45-264 msw), though the majority of these dives have been conducted in the 200-350 fsw (60-100 msw) range with typical bottom times of 20-30 minutes, ranging up to 60 minutes. Approximately 100 dives have been conducted in the 300-500 fsw (90-150 msw) range and only a handful in excess of 500 fsw (150 msw). These have been conducted by several leading cave explorers including; Sheck Exley, U.S., Jim King, U.S., Claude Toulomdjian, France and Jochen Hassenmayer, Switzerland.

The Safety Record

Dr. R.W. Bill Hamilton of Hamilton Research Ltd., Tarrytown, NY has been responsible for developing decompression procedures for a large number of these dives using the DCAP computational algorithm. Schedules from John Crea, Submariner Research Ltd., Bainbridge, GA, Randy Bohrer, Underwater Applications Corp., Nashua, NH, Kevin Gurr, Redding, UK and other sources have also been used as well. To date, the decompression experience has been good. In four reported incidents, two were "suspected" DCI and successfully treated with surface oxygen following the dive. Another possible DCI incident appears to have involved minor pain-only symptoms that was resolved without chamber treatment, an option which was refused by the diver. A final apparently mild DCI incident occurred following a 20 minute, 300 fsw (92 msw) exposure and was treated successfully with a USN Table 5.

With regard to operational safety, three fatalities, one "near miss," and a "blow-up" resulting in decompression illness, occurred during trimix diving operations in the U.S. in last two years, though these had little to do with the gas mix itself. The first fatality was due to a freak water reversal in an underwater cave near Tallahasee, Florida, that resulted in two divers being trapped during a deep mix dive. One of the team survived. The second fatality occurred on the *Andrea Doria,* when a diver separated from his partner during a wreck penetration run, ran out of gas after exiting and drowned. Several weeks later, another diver got lost in the wreck after getting separated the team's mainline during a trimix operation and drowned. In another incident, related to mix, a diver suffered a CNS convulsion during in-water oxygen decompression following a deep mix dive, when he lost buoyancy control, drifted down and "dozed off" at 35 fsw/11 msw (PO2=2.06). The diver, a paramedic, had only two hours of sleep the night before the dive. He managed to inflate his BCD before convulsing floated to the surface and was rescued by an excellent surface support team and resuscitated. A final incident was due to operational problems during a wreck dive— the diver missed the "down line" on descent, got lost, ran out of gas and was forced to "blow up" to the surface omitting decompression. He was rescued, evacuated to a chamber and treated successfully (See *"Safety First, An Analysis of Recent Diving Accidents,"* by Michael Menduno, technicalDIVER 3.2, *1992* for details). See Incident Report, pg.23 for update.

Methods, Procedures and Training

From a technological perspective, a focus of many of these pioneering dives has been to develop reliable operational procedures including gas mixes, reliable decompression methods, staging, and adequate diver support. Two groups, lead by Capt. Billy Deans of Key West Diver Inc., Key West, Florida and Jim King of Deep Breathing Systems, Sevierville, Tennessee, and several other individuals, including Sheck Exley have been responsible for much of this effort in the U.S. Much of this draws on the earlier work of the Wakulla Project conceived and led by Dr. Bill Stone *("The Wakulla Springs Project," edited by Dr.William C. Stone, U.S. Deep Cave Diving team, Derwood, MD.1989)*, the Sullivan Connection project organized by Bill Gavin, Bill Main, and Parker Turner and Sheck Exley's pioneering dives. Open water work utilizing heliox mixes has also been conducted by Ken Clayton, Washington D.C., Gary Gentile, Philadelphia, Pennsylvania, and Steve Gatto, Atco, New Jersey.

Key West Diver has developed many of the field methods and procedures for open water operations and has served as a training center for the majority of other technical diving operators, and many users in the US and abroad *(Presently there are about ten operators/user groups regularly conducting trimix diving operations and offering training— see below).* In parallel, Deep Breathing Systems has been responsible for developing many of the operational procedures and equipment for deeper exploration work. In addition, with the help of DCIEM, Toronto, Canada, Deep Breathing Systems has spearheaded the testing and validation of the decompression methods and tables generated by the DCAP algorithm using Doppler monitoring and other tests designed to measure decompression stress.

On the training side, the International Association of Nitrox and Technical Divers, (IANTD), Miami, Florida, led by Tom Mount, has pioneered the development of user and instructor trimix training programs, and currently has a roster of over 20 trimix instructors *(see the tek.GUIDE,* aquaCorps Journal N5, *1993, for facility and instructor listings)* . IANTD has made significant progress over the last year in developing training standards, texts and materials with the help of Dr. Lee Somers, University of Michigan, Ann Arbor, Michigan and is currently the only company offering formal trimix certification. IANTD has reportedly just obtained instructor insurance to cover its activities though rates are not yet available. Island Scuba Center, headquarters of the American Nitrox Divers Inc. (ANDI), has been conducting trimix dives for some time and plan to launch an extended range program later this year. In addition, there is at least one University trimix diving program at Florida State University, developed by Gregg Stanton. The British are also involved through IANTD UK, Somerset, England, headed by Rob Palmer, though their efforts to date have focused primarily on enriched air nitrox and some of the early development work on closed circuit systems. There is also some interest in Australia, spearheaded by Rob Cason, of Fun Dive Centre, Sidney, NSW, an IANTD director, and others.

Operating Guidelines

Though rudimentary training standards exist, there is as yet no written set of operating guidelines for self-contained trimix diving. However, an emerging set of "community" operational guidelines is developing with some success. *(See "Extended Range Safety Guidelines," pg. 19).* With regard to deep diving, the emerging "community consensus" is that dives beyond about 200 fsw (60 msw) should be conducted on a helium-based mix.

Today, most U.S. dives conducted in the 180-300 fsw (55-90 msw) range have standardized around the use of trimix 14-17/x, (14-17% O2 depending on the depth, maximum working PO2= 1.4-1.45 atm) with an *"equivalent narcotic depth"* (END) ranging from 85-175 fsw/25-53 msw (He% = 25-60%) depending on the exposure and application. Though "lean" trimixes with a helium content of 25% or less (an END of 175 fsw /53 msw at 250 fsw/76 msw), sometimes referred to as *"poor persons mix"* (helium-diluted air) on the basis of their relatively low cost and mixing ease, are sometimes used to reduce the risk of O2 toxicity and "take the edge off narcosis," the general thinking today is to eliminate as much narcosis as economically feasible. As a result mixes with at least 50% helium (an END of 85-118 fsw/25-36 msw at depths of 250-300 fsw/75-90 msw) are gaining in popularity and will likely become a community standard. Decompressions for these operations utilize a single enriched air intermediate mix, typically an EAN 32-36, which is breathed beginning at the first or early decompression stops, typically in the 110-130 fsw/33-40 msw range, followed by oxygen breathing at the 10 and 20 fsw/3-6 msw stops. Based on good success with these procedures, a set of provisionally standardized trimix decompression schedules for dives to 250 fsw (75 msw), known as the "Key West Consortium Tables," have been prepared by Key West Diver and Hamilton Research Ltd, to assist in standardizing operations and managing access to tables. These tables are unique in that they allow a "variable percentage of helium," and have been adopted by the majority of technical diving operators in the U.S., including Enchanted Diver, Floral Park, NY, The Gas Station, Gloucester, NJ, Ocean Odyssey, Santa Cruz, Ca, and Scuba Adventures, San Bernadino, CA. Schedules utilizing air as an intermediate gas have also been developed, by Underwater Applications Corp., and used with success where access to sufficient onboard enriched air supplies is a problem.

For deeper dives in the 300-500 fsw/90-150 msw, ENDs are generally set at 150 fsw/45 msw or less and decompression procedures typically involve air as an intermediate gas beginning as deep as 220-230 fsw/67-70 msw, followed by one or more enriched air intermediate mixes. For example, a typical procedure is to use an EAN 30 for stops beginning at 150 fsw/45 msw with a switch to EAN 46-50 at the 80-70 fsw/21-24 msw stops. This would be followed by oxygen decompression at 20-30 fsw/6-9 msw *(Note that the community consensus guideline is to limit oxygen use to 20 fsw/6 msw or less—ed.).* Doppler testing following these dives has suggested the use of air as a deep intermediate gas reduces decompression stress significantly, though the jolt of "instant" narcosis, and cumulative oxygen tolerance, must be managed with care.

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Mixed Opinion:

The British Sub-Aqua Club's Report On the Use of Enriched Air Nitrox

by Chris Allen

mix watch mix watch

In response to the growing interest and press regarding enriched air diving, the British Sub Aqua Club (BSAC) National Diving Committee formed a working group to review the use of mix technology in sport diving. The following is an excerpt of their report which originally appeared in the February issue of "Diver." Note that BSAC is a "membership" club that offers sport diving training and certification similar to that provided by the recreational training agencies in the US. The recognized sport diving range in the UK includes up to 50 metre (162 fsw) air dives with limited decompression.

Over the last twelve months or so there has been considerable interest in the use of gases other than air for sport diving, in particular the use of enriched air nitrox. In the USA, the subject generated a heated debate between the enthusiasts who claimed that "technical diving" offered a new direction for the sport, and the critics who believe that the use of any mixed gas other than air is outside the realm of sport diving. Though the U.S. debate over enriched air nitrox has cooled, in the UK many open issues and misinformation remains.

A common misconception in the UK is that the use of enriched air mixtures will allow sports divers to dive deeper depths than they could on air. This is not the case. By replacing some of the nitrogen in air with more oxygen, the resulting enriched air mixture offers a reduced decompression requirement for a dive to a given depth. However, the increase in the partial pressure of oxygen in the mixture also means that the threshold of oxygen toxicity occurs at a shallower depth than with air resulting in reduced operating limits.

In theory, any number of different enriched air mixtures can be produced from oxygen and nitrogen. In practice, however, most sport and scientific divers use one of two standard mixes established by the National Oceanic and Atmospheric Administration (NOAA) in the USA. These are referred to as NOAA Nitrox I, i.e. EAN32 (32% O_2, 68% N_2) and NOAA Nitrox II i.e. EAN36 (36% O_2, 64% N_2).

EAN 32 was originally regarded as having a maximum operating depth (MOD) of 40 metres (130 fsw) and EAN 36 a limit of 34 metres (110 fsw). However, recently the shallower limits of 35 metres (114 fsw) and 30 metres (98 fsw) respectively have been adopted in the UK to reflect a more conservative approach to oxygen management *(Maximum working PO2 =1.45 atm—ed.)*. By using a suitable nitrox mix in conjunction with a standard air decompression table or dive computer and performing the the dive as if it were on air, a diver can increase his safety margin against the risk of decompression sickness. Alternatively, the available bottom time can be extended by using an appropriate nitrox table, or by carrying out equivalent air depth calculations and using standard air tables.

The advantages of enriched air are claimed to be;

- Extended no-stop time limits.
- A reduction in decompression time if no-stop limits are exceeded.
- A reduction in residual N_2 in the body following a dive.
- Reduced nitrogen narcosis.
- Reduced risk of decompression sickness.
- A reduction in "Sub-clinical" DCI following a dive.
- A reduced rate of gas consumption.

It can be seen from a comparison of No-Stop times that the NOAA NNI tables, offers a definite and significant increase in available No-Stop time over air. However, calculating gas requirements against depth for a maximum No-Stop dive on air and EAN32 (assuming a 25% reserve and a surface breathing rate of 20 litres per minute—*about .7 cf/m*), it can be seen that for dives shallower than about 25 metres (82 fsw) most single tank divers would be unable to carry enough gas to be able to take advantage of the increased time available. In this case, extra bottom time is only a real advantage on dives in a relatively narrow depth band, between 25 metres and the 30-35 metre limit of the gas mix being used *(a range of about 80-115 fsw)*.

The claimed reduction in nitrogen narcosis seems to be widely accepted. However, attempts to measure this objectively have been unable to demonstrate any difference in performance and there is reason to believe that oxygen can produce the same narcotic effect as nitrogen (Linnarsson et al, 1990). Most experienced divers would probably not report any narcotic effects on air at depths shallower than the 30 metres maximum operating depth (MOD) limit for EAN36 anyway, so any advantage is likely to be restricted to EAN32 between 30 metres and its 35 metres limit (114-130 fsw).

If enriched air is used as the breathing gas and standard air tables are used to calculate decompression requirements then there will certainly be a reduced risk of decompression sickness. However, at depths shallower than 25 metres (81 fsw) the risk of DCI is already low, and this benefit is probably again restricted to a narrow depth band. If nitrox tables are used to gain more bottom time, the risk of DCI will of course be similar, although some slight benefit will be gained from the fact that nitrox is breathed at the decompression stop rather than air as assumed by the table. The evidence for claims that "sub-clinical" DCI is reduced for dives on enriched air nitrox, and that the rate of gas consumption is reduced, is subjective at best. "Sub-clinical" DCI is by definition undetectable *(except possibly on the basis of doppler measurements—ed.),* and therefore not really a problem. What's more is that minute volume is affected little by the proportion of O2 in a breathing mix.

In terms of the disadvantages of the use of enriched air mixtures by sport divers, critics have focused on the following points:

- The risk of usually fatal O2 toxicity if depth limits are exceeded.
- Equipment compatibility for nitrox use.
- The problems associated with gas mix and handling, including testing before use.
- Potential difficulties for hyperbaric treatment of a nitrox-breathing diver should DCI occur.

Are these disadvantages are really valid?

Oxygen toxicity of the central nervous system (CNS) can result in the classic oxygen convulsions which, due to the risk of drowning, are almost inevitably fatal if they occur at depth. Susceptibility to CNS oxygen toxicity is highly individual and can be affected by anxiety, exercise cold and CO2 retention. Unlike the gradual onset of nitrogen narcosis, CNS toxicity usually occurs without warning and is by no means only a theoretical risk. Last summer in the USA at least three divers experienced oxygen seizures; two while diving nitrox mixes resulting in fatalities and a third during his oxygen decompression on a trimix dive. The diver was fortunate to survive *("Safety First" by Michael Menduno, technicalDIVER 3.2. For additional incidents see "Oxygen: Good, Bad and Ugly," pg.23).* Though pulmonary oxygen toxicity has also been sited as a potential problem, today there is general agreement that it is not an issue in open circuit nitrox diving. It was this risk that mistakenly gave rise to the concern over treating enriched air divers in the event of a DCI incident.

With regard to equipment, most nitrox use is currently conducted with standard open-circuit equipment, though the "next generation" nitrox rebreather is probably not far away. Experience in the USA suggests that nitrox mixes containing up to 40% oxygen may be safely used with standard scuba equipment, providing it has been cleaned for oxygen service and providing air quality requirements are met. The mixture must be completely mixed before coming into contact with any equipment not suitable for oxygen service, and all lubricants used must be oxygen compatible. Although this is an area where there still remains some uncertainty, it is undoubtedly true that problems could occur if standard scuba gear is exposed to 100% O2 for example during mixing.

In addition, cylinders for nitrox use should be dedicated, labeled and colour coded accordingly. Gas analysis must always be performed before use. The depth limitations of the mix must be well understood and there must be no possibility of using the wrong equipment or gas mix. This is why the use of dedicated and identified equipment for nitrox is essential. The result is that divers wishing to perform dived deeper than 35 metres or occasional air dives will likely need to have two separate sets of equipment.

A further important concern over the use of nitrox is whether the sport diving community can cope with the mixing and safe handling of the gas mixes. Questions to be addressed here include oxygen handling, obtaining sufficiently clean air for the mix (see Air Quality pg. 34), making the correct mixture and gas analysis.

The working group's conclusions are that the use of nitrox has advantages in the middle depth range which may be of particular use for cave divers and scientific divers. However, for most sports divers, the disadvantages of nitrox are likely to outweigh the advantages on most dives. As a result, the National Diving Committee of the BSAC has taken the view that the general use of nitrox by sport divers in the UK is not appropriate. It has therefore decided that its use will not be permitted during any club-sanctioned activities. In the future, reliable microprocessor-controlled nitrox rebreathers may become an option. However, in the short term, air is likely to remain the breathing gas of choice for the vast majority of divers.

Chris Allen is the Secretary of the British Sub-Aqua Club and one of their senior instructors. Prior to chairing the BSAC Working Group on Mixed Gas he served as the BSAC Incidents Advisor for four years. He can be contacted at BSAC Headquarters, Telford's Quay, Ellesmere Port, South Wirral, Chesire L65 4FY. Fax: (051)-357-1250.

THE BSAC WORKING GROUP FINDINGS

ADVANTAGES OF NITROX	VALID	NOT VALID
Extends No-Stop time	X	
Reduced decompression times	X	
Reduced residual N2	X	
Reduced narcosis		X
Reduced risk of DCI	X	
Improved cellular integrity		X
Reduced sub-clinical DCI		X
Reduced gas consumption		X

DISADVANTAGES OF NITROX	VALID	NOT VALID
Risk of O2 toxicity	X	
Equipment compatibility	X	
Problems of gas mix/handling/testing	X	
Potential difficulties for hyperbaric treatment		X

AIR QUALITY continued from p.35

to 25 ppm. This figure is consistent with the CGA Level E, U.S. Navy, Fed Spec BB-A-1034 and other standards.

Morson is concerned that the agreed-upon specifications do not adequately address non-methane hydrocarbons that are the by-product of combustion or off-gassing of hydrocarbon lubricants, or from vapor degreasers. Many of these substances are known or suspected carcinogens.

"An example is benzene," Morson says. "The established TWA for benzene is 10 ppm on the surface."

Canadian Forces air purity standards require that only 1 ppm be present, and standards for pure or mixed gases are even stricter.

Wells is concerned that gas analysis doesn't go far enough regarding potential system failure.

"The danger arises from an accumulation of condensate on pipes, etc., in the system. These may be piling up each time you fill a cylinder. Over a period of time it could ignite. The stuff will be in the filters. You're going to blow your bloody filters up," Wells says. "An air quality test does not answer the question. It will not tell you what's sticking to the side of your system."

All oil-lubricated compressors are prone to condensate build-up within the system. Presumably a low level of condensate in the output air indicates the absence of appreciable condensate in that part of the system. Condensate may be present before the filters, but that air is not mixed with oxygen, so the issue is less critical. Additional testing is required to determine the presence of condensate.

The potential for problems would be eliminated by not using oil-pumped air for mixing, Wells notes. But he says he can see the dive operators' side of the issue, too. At NOAA, "we can afford to go to oil-less compressors."

The interim answer, he says, lies in strict system, cylinder and valve inspection and maintenance. Others agree.

"I think it will boil down to system cleanliness and filling protocols," says Deans. Seven gas panels now in place across the country are based on a design he developed in 1987. "You should make sure you're running clean before you start your operation."

"High pressure oxygen is used safely every day by industry, aviation, and in medical applications. These industries have learned that they key to oxygen safety is the use of specially prepared and compatible equipment by trained personnel following specific procedures," Butler writes in "Oxygen Safety in the Production of Enriched Air Nitrox Breathing Mixtures," co-authored with Stephen Mastro, Alan W. Hulbert and R.W. Hamilton. The paper was presented in September 1992 at the American Academy of Underwater Sciences 12th Annual Scientific Diving Symposium.

From left to right: Frans Vandermolen, Laura Betts, Ed Betts, Tom Mount, Richard Nordstrom, John Comly.

The argument about oxygen-compatible air specs may have an interesting payoff for all scuba divers. As the diving public becomes aware of air quality and system cleanliness issues, divers—even ordinary air breathers—may start to insist that all dive operators meet recognized standards for breathing air.

An aquaCorps contributing editor, Cathie Cush is a free-lance writer who specializes in diving, marine environment and technology, maritime history and dive travel. Her work has appeared in "Sports Illustrated", "Outside", "Carribean Travel & Life" and most major dive publications. A NAUI Member she can be contacted at PO Box 4243, Key West, FL 33041, Compuserve: 73777,2454, GEnie: C. CUSH.

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In response to the desire to maximize dive time at remote sites, for example, during offshore wreck diving operations, provisional repetitive trimix decompression procedures have been prepared by Hamilton Research Ltd. utilizing conventional gas loading analysis. This method is criticized by some experts, but there is no accepted computational algorithm for repetitive diving. Though the potential for being able to employ repetitive diving seems promising and will probably grow as trimix use becomes more widespread within the community, these tables have received only minor usage to date. More data is needed in order to refine the computational method. Work on altitude tables has also been done by Submariner Research Ltd. and Underwater Applications Corporation for specific applications.

The next boom in decompression management tools will likely come from the growth of *"desktop decompression software"*— computational algorithms running on a personal computer being pioneered by Corey Bergren of Cybertronix, Knoxville, Tennessee, Sheck Exley, Live Oak, Florida, Kevin Gurr of Aquatronics, Redding, England, and Dan Nafe, Miami, Florida *(see "Desktop Decompression Review," by Dr. Bill Hamilton & John T. Crea, pg. 11).*

The Operations Approach

To date, the field experience with trimix has shown that a rigorous *"operations approach,"* including thorough planning, proper equipment, diver support, competent execution, and the ability to respond and deal effectively with emergencies, is required to conduct these dives safely. Deep mix dives are by their nature complex because of the gas, decompression, and equipment management involved. There's a lot that can potentially go wrong. Simply breathing a mix is the easy part. The general consensus seems to be that the community still has a long way to go in improving operational procedures. In this respect a lot can no doubt be learned from the commercial diving community.

Over the next five years, trimix diving, supported by an "operations approach" and more in depth training, is expected to grow and become more accessible because of its safety advantages. As a result, trimix/heliox will likely replace the use of air for open circuit deep diving operations beyond about 180 fsw (55 msw), that is until reliable, low cost closed circuit systems find their way to market. *Take another breath.*—M²

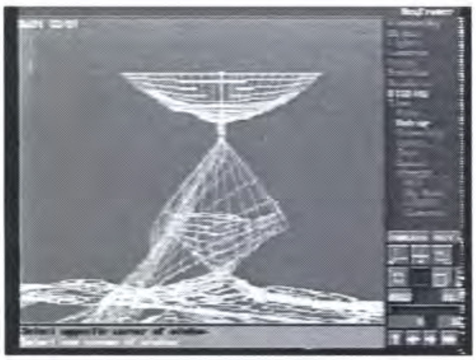
tekkie UK

The International Association of Nitrox and Technical Divers (IANTD) UK held their first technical workshop in Bristol, 25April1993, where an enthusiastic crowd heard Graham Laurie, representing the Health and Safety Executive (HSA) speculate that enriched air and mix diving are here to stay. Laurie went onto say that HSE's concerns were that an accepted set of training and operations standards be reached. Representatives from the major sport diving training agencies including BSAC, NAUI, PADI, SSAC, and SAA were also in attendance, and reported their positions on matters ranging from enriched air nitrox training to insurance.

Other topics addressed by IANTD UK members; Richard Bull, Kevin Gurr, Tim Stevens and Rob Palmer included IANTD training courses, instructor insurance, trimix diving and the future of closed circuit technology. Several major manufacturers were also in attendance including DUI, Northern Diver and Oceanic indicating that the UK diving trade is beginning to take technical diving seriously.—*Rob Palmer, Bristol, England, f: 0749.848.685.*

Mapping Eagle's Nest

During the Eagle's Nest project, our team was faced with finding a suitable way of mapping the cave system. As we explored, several options were available; but, wanting to be pioneers, we wanted to create the first



three-dimensional map (rather than the often used stick map). This would allow us to examine the cave system from different angles or views, hoping to connect passages more easily. The team chose Autocad because it also allowed for measuring bearing and distance from point-to-point, volume of a given area and, of course, the 3-dimensional viewing.

Data was collected as follows: at every 50' interval the bearing, depth and distance to right wall, left wall, ceiling and floor were noted. This allowed the formation of a single vertical plane. The computer then connected the vertical planes formed during the survey with straight lines to form a tunnel. The outer surface of the tunnel can be shaded automatically to form a solid object; hence, the 3-dimensional cave.

Data collection can be extremely time consuming as we measured some areas several times in order to get accurate "closing" on several rooms. Often Larry Green and I would have to travel 2000 feet in one direction requiring 20 minutes at 240-270 fsw (74-83 msw) *before* beginning our survey work. Trimix was always used to help improve the accuracy of our data collection. The end result is a 3-dimensional image that can be viewed and photographed from any perspective.

Exploration diver, Jim King, is the President of Deep Breathing Systems and a regular contributor to aquaCorps. *He can be contacted at: PO Box 4220, Sevierville, TN 37864. f: 615-428-3446*

TOOLS ACCESS

Adobe Photoshop, Adobe, US, p: 800.833.6687• **Autocad • Bridge**, Dive Rite Mfrg. US f: 904.755.0613, UK 753.841.686• **Computer video image digitization (CVID)**, Creative Images, US f: 919.732.6197.• **CRADOC CaptionWriter**, Perfect Niche Software Inc., US, f: 602.945.1023• ***Cyberspace—See listing pg. X*• DCAP**, Hamilton Research Ltd, Us, f: 914.631.6134• **DAWN**, Trident Miniatures, f: 404.469.5324 • **DIVA**, Stolt Comex Seaways, France, f: 91.40.12.80 • **DPA**, Cybertronix, US, p: 615.977.0360• **Dr. X's Dive & Deco Planner**, DEEP Inc. Rt.8, Box 374, Live Oak, FL, 32060, US• **EDGE, Delphi, Phoenix, Dive Profiler**, ORCA Div. of EIT, US f: 703-478-0815• **Excel**, Microsoft, US, p: 800.323.3577• **IRIS Explorer 2.0**, Silicon Graphics, US p: 800.488.1414• MIG Technologies, US, f: 305-599-1140 • **Mix Master**, Ocean Diving, US, p: 305.943.3337 • **Newtsuit**, International Hard Suits, Canada, f: 604.984.9138• **ProPlanner**,Aquatronics, US, f: 305.751.4873, UK, f: 635.874.188.• **SMAPS**, Speleo Technologies Inc., P.O. Box 293, Frostburg, MD, US 21532• **Virtual 'S' Translator Tool**, Virtual S, England p: f: 081.392.242 • **PDA**, VisionTECH p: 800.858.8317 •**YSI 6000 Sonde**,YSI Inc., f: 5163-767-9353. These products are discussed in this issue of a/c Journal.

erratica

Market Bent

The "BENT" editorial by Michael Menduno, "aquaCorps Journal," N5, incorrectly reported that a US company would soon be releasing a portable chamber priced in the $18,000 range. Currently, SOS Ltd's inflatable "Hyperlite" chamber is the only non-metal portable chamber on the market and is likely to remain so in the near future (see "Portable Chamber Technology," by John Selby, *aquaCorps Journal*, N5). Priced in the neighborhood of about $25,000, the Hyperlite represents a major breakthrough in chamber technology.

Many individuals, including the aquaCorps staff, believe that portable chambers are the way of the future—*particularly for technical diving applications*. With volume, prices are expected to fall and within five years, portable chambers will likely become a ubiquitous part of the diving scene. It only makes sense. Though the use of surface O2 is an advantage, field experience shows that *immediate* recompression following a DCI incident is a key to successful treatment provided you have the facilities. Ultimately the question will come down to, "Who would YOU rather be diving with: The HAVES or HAVE NOTS?" M2

Where credit is due.

We inadvertently omitted a photocredit for the Winter cover of the tek.GUIDE, *aquaCorps Journal*, N5. This photograph of Parker Turner was taken at Cheryl Sink in1989 by Wes Skiles, Karst Productions, High Springs, FL, just prior to Turner's "Sullivan Connection Project" dive conducted with Bill Gavin and Bill Main. In 1991, Turner was tragically killed in an underwater cave-in resulting from a freak flow reversal at Indian Springs system. A pioneer and instructor, he was loved and respected by many.

DEEP THOUGHT

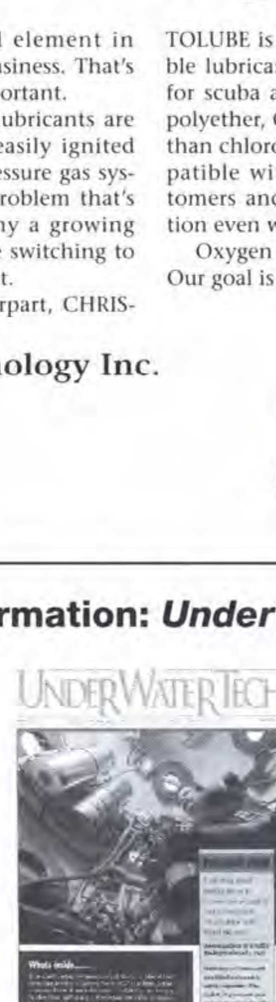
The Europeans, led by Carmellan Research Ltd. may be nosing ahead in the race to get a 'low cost' closed circuit system to market. Carmellan Research signed a marketing agreement with Dragerwerk AG last year to produce and market the military and commercial versions of their system, the SMS 2000. The unit was on display at tek.93. Carmellan is also reportedly signed an agreement with Oceanic, San Leandro, CA to market a sport diving model in the States with a training program to be provided by ANDI, Freeport, NY. Learn about close circuit technology and its market prospects in our coming issue, *aquaCorps Journal* N7, "C^2."

Rob Palmer, Carmellan Research, holding a Lucayan Indian skull, one of 16 found, in Sanctuary Blue Hole, South Andros Island during closed circuit operations.

tekkie award

The ***"tekkie"*** was awarded to Dr. R.W. Bill Hamilton at the tek.93 Conference for his significant contribution to the philosophy and development of technical diving. Created by sculptor, Agustin J. ("Auggie") Rodriguez, Trident Miniatures, the sculpture was cast in 20 bonded bronze pieces with an additional 16 pieces of brass, copper, and steel (not including hoses), and stands over 9" tall. The manifold alone has 13 components. A limited edition collector's version of the "tekkie," titled *Dawn*, will be available soon from Trident Miniatures: PO Box 567, Stone Mountain, GA 30086, f: 404.469.5324.

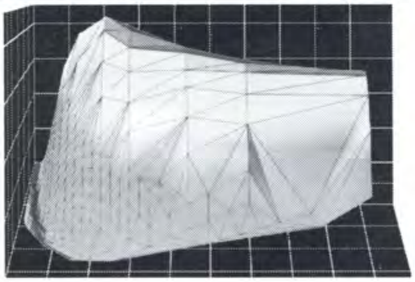
Inside Information: *UnderWater Tech*



Keep informed on developments in commercial underwater technology with ***Underwater Tech***, a new international digest of current issues for end users published by founding editor of *Underwater* magazine, Cavett Hughes, Houston, TX. Targeted to industry insiders as well as end users, ***Underwater Tech*** covers news and developments in the underwater industry while reviewing the latest trends in commercial underwater products and services, from wet welding to telerobotics. Note that ***Underwater Tech*** is one of the sponsors for the **1994 tek conference** and will be hosting sessions for commercial diving participants.

For more information contact: Cavett Hughes, UT, 9449 Briar Forest, Suite 3109, Houston, TX 77063-1738, p: (713)780-4380, f: (713)780-4172.

"Computers are useless. They can only give you answers."
Pablo Picasso



vendor index

Beyond The EDGE

The *Classic*: Introduced in 1983, The **EDGE** dive computer along with its patented "tissue compartment graphics" display launched a revolution in dive computing.

The **Marathon** is a highly reliable low cost computer designed for 'no-stop' diving offering user-changeable batteries and an enlarged information display.

Having launched a revolution in 1983 with the introduction of the EDGE dive computer, ORCA has been quietly beating a path to the future for over a decade.

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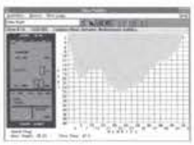
Configurable for either Air or Nitrox, the **Phoenix** offers EAN32 compatibility, integrated gas supply monitoring and look ahead; and extended data logging capability.

The ORCA **Dive Profiler** lets you download and analyze dive profile data in a Windows environment. Future versions will include a decompression simulator. Desktop decompression anyone?



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____	***aquaCorps Journal N6, "BENT"*** w/ Special *tek.GUIDE* Resource Directory.	$15 ea. ($3 p&h)
____	**technicalDIVER 3.2**, "Safety First," including an analysis of 1992 'technical-level' accidents.	$5.95 ($2 s&h)

1994 tek Conference (9-11JAN94, New Orleans USA):

Qt.	Item	Price
____	**Conference Package:** Includes Sunday night cocktail party, all conference sessions, tracks and exhibits. Does not include lunch or evening show. *Registrants receive a free one year subscription to* Scuba Times *and* Underwater Tech *magazines.*	Special $99 adv. registration expires 31AUG. $150 at the door/ members $125.
____	**tek Banquet Lunch** (Tues. 10JAN94). Key Note speaker (to be announced) plus full banquet lunch.	$25 Limited seating
____	**Evening Show:** *"A Virtual Evening"* focusing on the latest underwater computing and imaging technologies.	$15
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Hotel: Call The Mariott at 504-581-1000 for special tek rates. **Airlines:** Call 1-800-872-8208
tek Exhibits: Contact The Tech Reps 1.800.926.8045 f: 407.288.0220

"Talk tek to me" (video):
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