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 available. 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.

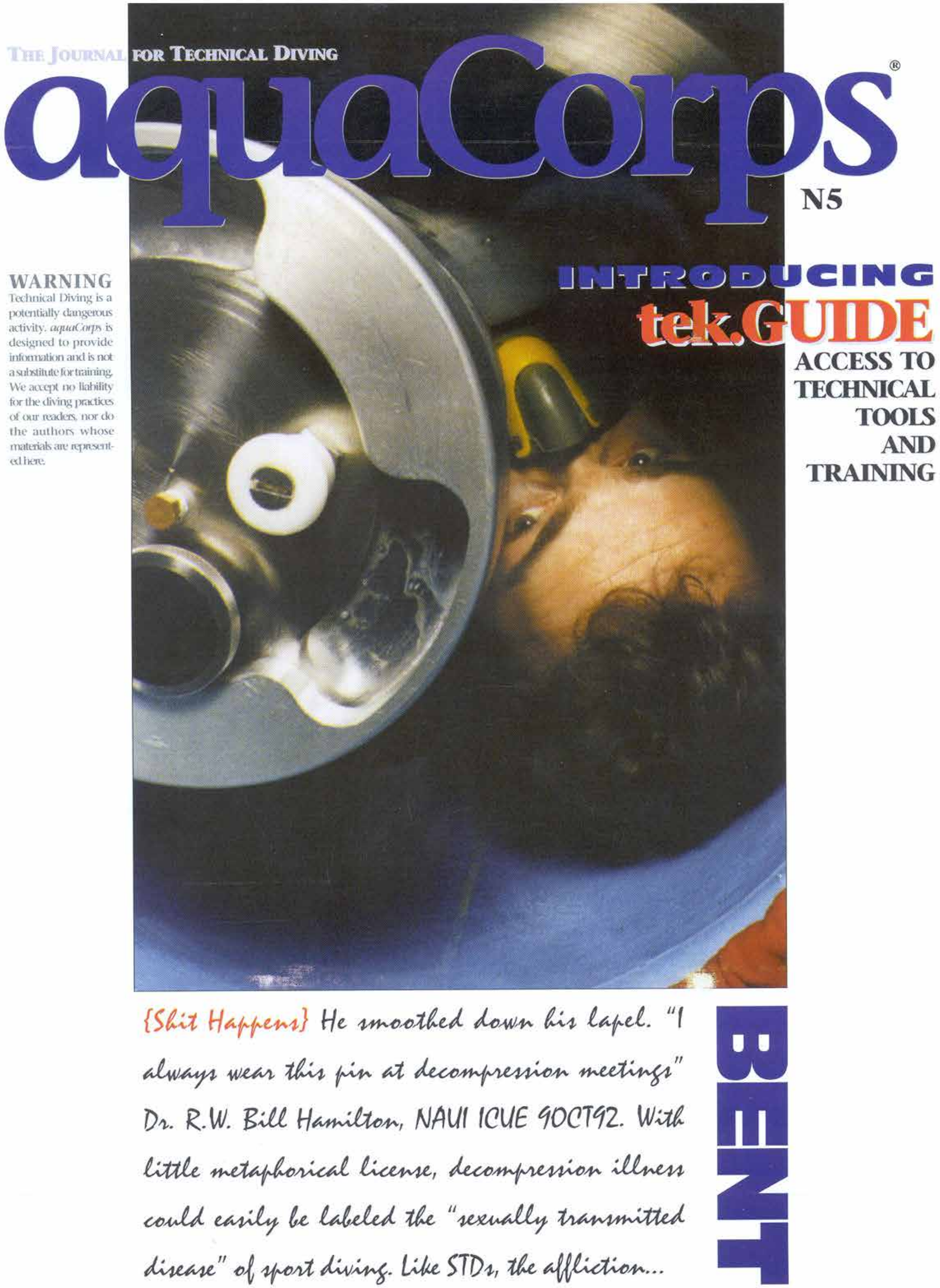
Within two years I coined the moniker "technical diving," to distinguish this type of diving from recreational diving, and the name stuck, as tech diving began to gain momentum and spread around the globe. In parallel, the magazine, which we subsequently rechristened, aquaCORPS: The Journal for Technical 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, aquaCORPS ran out of money and I was forced to close the company. By that time, we had produced a total of 12 themed issues of aquaCORPS and four issues of technicalDIVER, along with 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 later, I have begun to release sponsored, digital copies of the original magazine including the aquaCORPS MIX issue, C2 (rebreather) issue, and this issue of BENT. I want to thank my illustrious, sponsors, all of which are pioneers in their own right, for making this possible. You will find some of their content inside, 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



April, 2022—Nearly 30 years ago, we devoted an issue of aquaCORPS to the subject of decompression illness (DCI). It was titled "BENT" and presented the latest thinking on the theory, classification, treatment, and human factors associated with DCI. In fact, it featured the work of some of the top researchers in the field including; Carl Edmunds, T.J. R. Francis, RW Hamilton, Jennifer Hunt, Phillip James, CJ Lambertson, Surgical Capt. Pearson, Capt. Ed Thalmann, Richard Vann, and John Zumrick. Note that mixed gas dive computers were not available yet, and so virtually all technical dives were conducted with tables, either generic or software-generated for the specific dive.

At the time, tech divers were pushing our underwater envelope in terms of depth and time, and we expected incident rates to increase accordingly. Unfortunately, there was also a considerable amount of blame and shame associated with DCI, and affected divers often didn't report the incident and or were in denial. In my editorial, I likened the stigma of getting bent to that of contracting a sexually transmitted disease (STD).

For this digital re-issue, I thought it would be interesting to reach out to some of DAN Europe's leading hyperbaric physicians and ask them to weigh in on how our understanding and treatment of DCI has changed over the last 30 years and add it to the original issue published in January 1993, along with some information from our sponsor DAN Europe. Here's what their doctors had to say about the changes in our understanding and views towards DCI. Feed your head—Michael Menduno

What would you say are the most significant changes and or improvements in our understanding about DCI/ DCS, over the last thirty years?

Costantino Balestra (CB): We have less confidence than we used to in trying to understand decompression sickness (DCS) with a purely physics-based approach relying only on saturation and desaturation. We now understand that activities undertaken before the dive are important, as is the diver's general health. Both affect the population and diameter of micronuclei (in the micro world) and/or Static Metabolic Bubbles. (See Alert Diver: It's The Metabolism, Stupid: A New Model for Bubble Formation.)

Other interesting discoveries include heritable traits that offer some DCS protection, as well as minor differences in susceptibility between males and females. Finally, microparticles can act as "second-generation micronuclei" and facilitate DCS, depending on your pre-dive activities.

Peter Germonpré (PG): For a long time, DCS was considered a "bubble disease", with symptoms related to ischemia caused by entrapment of bubbles in small blood vessels. Over the past 15 years however, a number of biochemical effects caused by inadequate decompression have been discovered. These systemic inflammation reactions may well be equally or even more important than the purely ischemic effects. What's more, the biochemical effects appear to be present even if no bubbles can be detected by doppler or echocardiography techniques. Finally, there appears to be a correlation between between how the body responds to this inflammation and the outcomes of recompression treatment for DCS.

Alessandro Marroni (AM): The difficulties encountered when trying to "mathematise" biology left us with gas physics as the only viable basis for decompression models. This resulted in a series of developments, beginning with the revision of Haldane's original 2:1 critical supersaturation ratio, the introduction of considerations for physiological factors, e.g. with Buhlmann's A, B and C models and the inclusion of data on estimated cardio-respiratory stress. These were followed by the advent of probabilistic models based on outcome likelihood, like the US Navy tables, and later bubble models (Yount et. al.) and Bruce Wienke's gradient-bubble approach, which was supported by an outcome-based dive database.
All these models were created in response to DCS events occurring after dives that would have been deemed "safe" by the "The Tables," which were subject to empirical adjustments. Fortunately, Haldane had it almost right. His work saved thousands of lives and prevented even more DCS cases. The empirical adjustments, which were based on sound theory, were only able to make make small, albeit still significant, improvements.
The most significant development was and remains the reclassifications of DCS as a biologically-driven illness, where inter- and intra-individual changes play a role. In this new approach, bubbles play a role as a trigger but are not the only factor under consideration – an individual's physiological and pathological response can make the difference.

In my opinion, current improvements in our understanding are driven by the unprecedented wealth of data collected from tens of thousands of fully-monitored dives, which are being scientifically and epidemiologically evaluated by multiple research groups around the world. Thanks to the participation of so many divers who donate their computer logs to science, researchers have been able to pursue more in-depth studies to better explain the many individual differences observed. This has led to more detailed studies involving blood chemistry, genetic factors, origin, prevention, and treatment of divers' responses to stresses of compression and decompression.

Last and not least, these developments highlight the need to further investigate skills, tools and methodologies to monitor divers' behaviour and physio-pathological responses underwater. This has led to the development of advanced underwater telemedicine technologies.

Adel Taher (AT): We now have a much better understanding of:

- The origins of bubbles,
- The mechanisms of inflammatory reactions,
- The "Oxygen window",
- Isobaric counter-diffusion (ICD),
- The mystery of "undeserved hits",
- Utilising heliox (HeO2) as a gas in the treatment of DCS/DCI incurrent in sport and recreational diving,
- Recognizing that DCS is to a great extent a disease affecting micro-circulation.

How about in terms of treatment protocols? What have been the most significant changes/developments, if any, in that period?

CB: There have not been many changes, except maybe the addition of treatment with anti-inflammatory, lidocaine, or aspirin. As far as In-Water Recompression (IWR) is concerned, it's still under debate. However, the use of full face masks with communication and other equipment for IWR, in conjunction with improved training, has improved safety.

PG: Treatment protocols have not changed much, although there now is a general consensus that treatment tables should be high-oxygen, shallow depth (meaning US Navy Tables 5, 7 and equivalents, such as Royal Navy and COMEX tables). Heliox may be used as a treatment gas for slightly deeper recompression, and avoiding oxygen toxicity but may have a therapeutic benefit by itself. However, owing to divers' varying presentation of DCS and the paucity of hyperbaric centres, it is very difficult to formally test the efficacy of one treatment protocol against another.

Recent consensus regarding In-Water Recompression recognizes IWR as a useful and effective form of treatment in remote places. However, it has significant risks and should only be undertaken by a trained group of divers who have set up all the necessary treatment and safety equipment beforehand and have practiced the procedure. Medical guidance is essential. In my view, IWR should be evaluated similarly to a hyperbaric chamber on-site: If the chamber has not been set up and tested beforehand, if no-one has been trained to operate the chamber, or if there is no medical guidance on how to select a protocol and monitor the patient during treatment, then it should not be used, as it may be more dangerous than helpful.
AM: Frankly, there have been few changes. Thirty years ago, the main approach was to treat all surface-to-surface diving injuries with the Workman and Goodman Oxygen Tables, and this is still so, although some approaches for introducing 4 ATA Helium-Oxygen tables (such as COMEX CX 30 and variants) are being used successfully. Now that the inflammatory nature of DCS is better recognized, we also have more insight into the use of drugs as a complement to hyperbaric oxygen treatment (HBOT) and the importance of proper hydration during treatment. All in all, in my opinion, the treatment of DCS has been pretty consistently based on the original

US Navy Oxygen Tables.
In-Water Recompression, which has been debated and generated some controversy, deserves a few words. It was initially overhyped, then demonised. In my opinion, it may have a place when other modalities are not feasible, specifically when the diver is at a distance from the nearest chamber that would make evacuation impracticable. Similarly, much has been written about mild DCS cases being treated with normobaric oxygen and fluids only, especially in remote areas. But the truth is that neither is an "easy way out."

IWR and normobaric oxygen treatment both require technical knowledge, logistics, adequate materials, and staff. They both require knowledge, as well as the ability to conduct an evaluation and reach a differential diagnosis. Both would be better done with the assistance of a remote expert on the phone, radio, internet, or even with the aid of the modern telemedicine tools. As I said, they are not the easy way out.

When a diver or a group of divers undertake expeditions or exploration dives where such difficulties may be encountered, then awareness, preparedness, competence, skills and practised drills may make the difference between success and catastrophe.

AT: The dawn of organised research through scientific entities such as the UHMS, EUBS, GTUEM, OEGUHM, ECHM, EDTC, DMAC and DAN Europe has helped establish codes of good practice and guidelines.
USN TT 6A is not popular anymore as the sole treatment for AGE/CAGE, Introducing the classification of symptoms into "mild" and "severe" has opened the door for the treatment of "mild" symptoms with normobaric oxygen and adequate hydration rather than compulsory recompression in remote areas.

In-Water Oxygen Recompression has finally been accepted as an emergency modality for treatment when a recompression facility cannot be reached, provided a trained team and all adequate equipment are available and safe oxygen partial pressures are respected. Some tech training agencies now teach In-Water Recompression as a specialty course.

The relation between proper on-site first aid and oxygen delivery, using normobaric oxygen during transport, and the number of treatments has been established.

Has the incident rate of DCS among sport divers improved over the last thirty years? Why or why not?

CB: There have not been many changes, although we now understand more about DCS and the procedures for tackling it. We have probably reached the maximum of what can be done without changing procedures.

PG: It's difficult to say — many divers still do not seek out advice or treatment unless they have been severely affected. Diving safety organisations such as DAN, of course, collect data, but even that is only partial and may be biased through coming from a safety conscious population, i.e. DAN members.

AM: I would say not. The reason is, that in my opinion, divers do tend to dive very conservatively, irrespective of what they tell after their dives! A study done 30 years ago over 21,000 recreational dive profiles, showed that 80% of the dives were completed within a gradient factor (GF) of 60, just under 20% were completed with a GF between 60 and 80, very few ended with a GF between 90 and 100 and only a single-digit number beyond 100! Not surprisingly our 2017 study of nearly 40,000 fully-monitored dives showed similar results. If divers had been regularly diving close to the sanctioned and allowed limits, we'd probably have witnessed a different incidence rate.

AT:

- In the South Sinai we have not observed any evident improvement, although I have to say that we do not know the exact number of dives made in the last years. So, my answer is more speculative than factual.
- We have observed a low level of diving and dive safety education in the current dive generation. Instructors' knowledge level is below average in matters of diving physiology and pathophysiology of DCI
- Some divers "buy" their certificates in their countries and, as a result, have very little knowledge of diving physiology and low safety awareness.
- Divers dive beyond their level of experience, and some dive operators allow that for financial gain.
- We also have to consider "ageing" divers who learned how to dive in their 70s and early 80s. They have chronic diseases and are taking medication and may not be eligible or fit to dive, but many still dive.
- A positive impact was achieved by introducing nitrox [to the sports diving market], especially for dive professionals that do extra dives securing moorings and tying up their dive vessel (e.g. on trips to the Thistlegorm).

In your opinion, have dive computers increased DCI safety, reduced it, or had little or no effect?

CB: They are maintaining the status quo but may have slightly reduced the incidence cerebral arterial gas embolism (CAGE), since the ascent speed is more controlled.

PG: Thirty years ago, we used to treat a lot of DCS that was presumed to be caused by the diver not adhering to the dive tables. Nowadays, it is extremely rare to see a diver who did not "follow the computer." In that respect, diving has probably become safer with dive computers.

On the other hand, divers tend to trust their computer's calculations often over and above common sense. Unlike tables, dive computers allow any number of dives in a day as well as reverse dive profiles, and many divers do not understand the concepts that govern dive tables (and are still applied in the computer's algorithm). The most commonly heard statement by divers with DCI must be, "I don't understand why I got bent, my computer said everything was fine."
AM: To some degree, yes, they have increased safety, as they made respecting the tables or algorithm easier and less

based on memory, compared with having to regularly check your watch, the depth gauge, and then the tables. Computers make our life easier and following the rules simpler.

But back when computers did not allow for setting certain parameters, they were subject to the same errors in predicting DCS as the tables or original algorithms they were based on. A major breakthrough was the introduction of user adjustable settings such as age, water temperature, altitude, initially, and later settings with more delicate parameters such as gradient factors (GFs) or O2 fraction. However, many divers adjust these settings without proper knowledge and understanding, so they may end up doing more harm than good.
Many modern computers now include even more sophisticated features, and a generation of computers that will adapt to an individual's physiological response to diving and deco stress is coming. This, together with recent advances in the knowledge of the complex physiological mechanisms involved in decompression make me very confident in a brighter future for diving and diving safety.

AT: This is a difficult question to answer! I personally believe that they have increased accidents. That is because divers typically do not take into account the 'limitations' of dive computers and the algorithms used.
A dive computer will never know if you are on medication or not, if you were dehydrated and suffering electrolyte imbalance or not, or at the extremes of age.

The presence of dive computers made many training agencies stop teaching the dive tables. As a result, many new divers lack the basic understanding of how the calculations are made to deal with the residual nitrogen, and repetitive dives. They rely entirely on the dive computers and generally have no backup if anything goes wrong.

I always ask patients that come in with accidents about the computers they were using. Shockingly, 65% of them never read the instruction manual!
I personally use two dive computers and always keep a dive table in my BCD pocket.

Do you find that there is still a stigma about "getting bent" like there was in the late 1980s/early 1990s?

CB: Maybe not stigma, but many divers are in denial.

PG: As a diving doctor treating divers with DCI, I see it all the time. Many divers have the belief that "it will not happen to me." In addition, many divers think that if they have done the same dive 10 times without incident, the dive will ALWAYS be safe. Still, we see divers falling into a psychological void after getting DCI, believing they are "weak" for getting bent. Additional education about statistics would be useful for all divers.

AM: Frankly not— at least in the wider recreational diving community or even in the technical community. The more knowledge in the community, the better this is understood, and the greater the awareness of prevention. Getting "bent" is part of the game, and today there are many more tools to prevent it than before, when it was seen as a deficiency in the diver. Murphy's corollary to Dr. RW Bill Hamilton's declaration, "Shit happens" :-)

AT: The one thing that remains unchanging isn't the stigma, but the denial. However, there is still some stigma among dive centres; they do not want competitors to see the rescue boat headed to their dive boat to pick up an injured diver.

Do you foresee any significant developments in the future that will impact how we avoid, manage, or treat DCI?

CB: Yes, if we consider what has been learnt, and acknowledge that PFOs don't explain everything.
PG: I think we have come to a point where for recreational diving, the decompression algorithms and dive computers are as good as they'll ever get, and where further improvements will be difficult to achieve. However, I think that diving instruction should focus more on the physiological aspects of tissue saturation and desaturation, in order to help divers understand that dive computers are a tool, not the truth. A certain extra level of safety must be planned to account for the many uncertainties still present in diving physiology. I often compare a dive computer with a GPS used for mountain hiking in thick fog — you would never go to within 10 cm of the cliff's edge if you could only see it on the GPS screen and not with your own eyes. Ironically, divers often do just that!

When two divers do the same profile on the same dive, and one gets bent and one doesn't, this is most likely due to individual physiological differences. This seems obvious for easily observable differences like age, sex, weight and general health, but there are many other factors (differences between individuals but also within the same diver, changing from one day to another) that probably play a role, and about which we still do not know enough. Current and future research will focus more on these factors as a way to understand why someone got bent, and then in a later stage, propose ways to achieve a more "individualised decompression."

AM: I have already highlighted them above. I believe the future is in telemedicine and the advancements in modern field research, especially that currently conducted at DAN Europe.

AT: I do not foresee a magic pill that you take before diving that will prevent DCI. Even with the genetic predisposition studies showing that some divers are more prone to get DCI, others are bubblers, while others rarely bubble, things will not change dramatically.

Diving Safety is a matter of common sense, and common sense does not seem to be very common at all! We need to create a new generation of dive professionals with a solid foundation in diving physiology and the pathophysiology of DCI. Training agencies should put a bigger emphasis on diving medicine in their basic training and not oversimplify matters.

Thank you everyone!

Readers, here is the original issue of BENT as it appeared in January, 1993.

aquaCorps N5

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aquaCorps Journal N5, "BENT" was published 1993 January.

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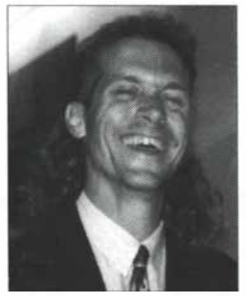
ABOUT THE COVER: Diver on oxygen BIBS mask, looking out from the SOS Ltd. Hyperlite portable chamber. Photograph by Keith Morris, London, England.

BENT

{Shit Happens} He smoothed down his lapel. "I always wear this pin at decompression meetings" Dr. R.W. Bill Hamilton, NAUI ICUE 9OCT92.



With little metaphoric license, decompression illness could easily be labeled the "sexually transmitted disease" of sport diving. Like STDs, the affliction strikes divers engaged in an activity that is fundamental to their nature. What's more is that there is a disproportionate fear and stigma surrounding DCI suggestive of "moral disease," and a surprising lack of understanding regarding the disorder on the part of divers and the industry as a whole.

Though the origin and cause of this phenomena is complex, the situation is not unique to sport divers. In fact, the need to "decriminalize" DCI, the subject of a recent U.S. Airforce workshop, has been a long standing issue in scientific, commercial and government diving, as well as in aviation. As summarized by one astronaut at the workshop , "Reporting DCI is not exactly a career-enhancing move."

This inability or unwillingness to face the facts is the real danger surrounding decompression illness, and in the case of technical diving, an obstacle to its potential growth and development. In order to improve safety— *one of the fundamental objectives in technical diving*— we need to be able to straighten out our approach to DCI and remove its associated stigma and fear. Perhaps the first hurdle is better recognition of the statistical nature of decompression itself.

The popularized Haldanian view of the world held that DCI was deterministically predictable, that there were absolute limits. One side of the line represented safety, the other DCI. Though this view persists, perhaps in part, for the convenience of teaching, it has long been known to be untrue. Haldanian algorithms work with an "acceptable" degree of reliability, because they are calibrated to real world data—*"what works, works."* Today leading research has shifted to statistical modeling pioneered by individuals like Paul Weathersby, Shalini Survanski, Ed Thalmann, Hugh Van Liew, Richard Vann, Bruce Wienke and others.

As Dr. Hamilton's decompression pin alludes, the view today is that **DCI is not an accident**. It happens and will continue to happen as a *predictable* part of diving. No significant dive is free of the risk of decompression illness, and it is generally acknowledged, that the risk on some of todays technical-level exposures may be high. Richard Vann, Duke University (see "Decompression Safety" pg. 10) estimates the overall sport diving incident rate to be about 0.02% or about *"one incident in 5000 dives."* Given that the risk for some technical-level dives could reasonably be as much as 5-10 times greater, or *"one incident in 500-1000 dives* (an incident factor of 0.1-0.2%)," it is likely that most technical divers will get bent at least once in their diving careers and probably more. Again quoting Hamilton, "It's just like being a cowboy. If you ride a horse enough times you are going to get thrown. Expect it and be prepared to climb back on."

Given that DCI is and will remain an integral part of technical diving (and diving in general), what should be done? There are several competing approachs. The unspoken recreational "weltanschauung," might be summarized as follows: DCI is a result of violating the limits (see *"Straightening Out The Bends"* pg. 16) and in most cases means an end to the individuals diving career. The few hapless victims of "undeserved" DCI represents an unfortunate fluke. This view is not very accurate or useful. In contrast, the approach taken by the commercial world seems more applicable to technical divers and potentially

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Lifetime members
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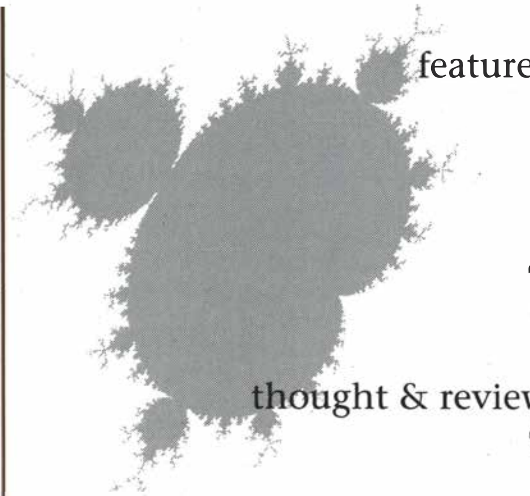
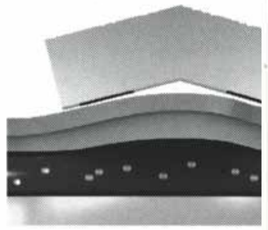
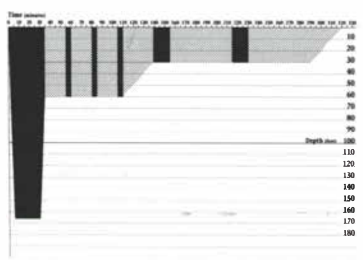


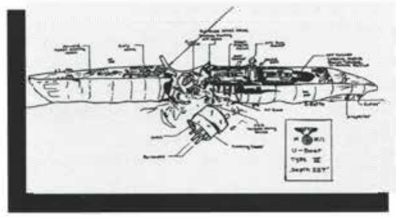


USN Table 6a

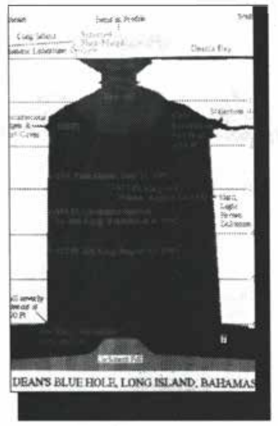


Field Notes

First discovered 1Sept91 by divers on the *"Seeker,"* captained by Bill Nagle, the unidentified WWII German U-boat, the *"U-Who,"* laying 63 miles northeast of Manasquan Inlet, New Jersey, in 230 fsw (70 msw), has been a source of exploration, and three fatalities (see Incident Report," pg. 51). According to veteran divers, Steve Gatto, 31, and Tom Packer, 35, Atco, NJ, the sub is fully intact except for the control room, conning tower, and a large hole aft of the torpedo loading hatch in the stem that shows evidence of being blown inward. Entry into the wreck is tight, and once inside, no ambient light penetrates. The sub is full of debris, silt and tight restrictions, and lighting cables hang down from the ceiling increasing the chances of entanglement. Reports Gatto, *"The discovery of torpedoes, dishes and potash canisters supports the theory she was lost in action, but the real clincher was the discovery of masses of bones."* The U-boat has yet to be identified.



Steve Gatto, 33 Pamela Ct., Atco, NJ 08004.

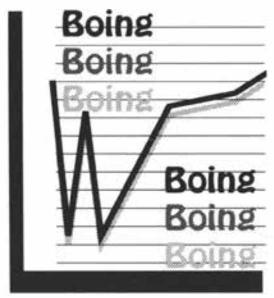


Jim King, 42, Sevierville, TN. reported that the Deep Breathing Systems team conducted a week long exploration of *Dean's Blue Hole*, Long Island, Bahamas. The exploration team made a series of dives to locate connecting cave passage and laid over 4000 feet of survey line. The dives included a 12 minute descent and bounce to 670 fsw (206 msw) on trimix 8/70 (8% O2, 70% He), utilizing three intermediate mixes and O2, requiring about five hours of decompression on DBS's computer generated tables. Dean's is the deepest known blue hole and represents one of the largest underwater rooms found to date. The volume of water displaced during a tidal cycle indicates that there are many miles of cave passage connecting to the system. A full technical report is available.

Deep Breathing Systems, PO Box 4220, Sevierville, TN 37864.

Field Notes

Transvaal Underwater Research Group, led by Mike Bailey, Dave Kleinman, and Andy Gray, Rosettenville, South Africa, conducted a series of deep "air" bounce dives (5-7 min. descent & bottom times) to 100-102 msw (330-337 fsw) in *Danielskvil* cave system, elevation 4000 feet, in Northern Cape Province, South Africa, using modified US Navy Tables. Work up dives ranging from 40-70 msw (132-230 fsw), were conducted prior to the series of jumps. The group intends to add in-water oxygen to their program and is currently investigating the use of trimix for more extended exposures.



T.U.R.G., PO Box 47, Rosettenville, South Africa 2130

One of France's top cave diving teams, led by Claude Touloumdjian, and Frederic Bernard, Marseille, France, have been conducting a series of 30-40 min. cave explorations (4-5 hour runtime), in the 100-120 msw (328-394 fsw) range in southern France, using trimix, an enriched air intermediate mix and O2 at 9 msw (30 fsw), utilizing French commercial-based tables and "Zepps." In order to counteract the effects of the *chill* 8-10° C (48-50° F) water temperatures, the team has suspended a "microbell" at 6 msw (20 fsw), constructed from a large inverted plastic garbage dumpster found "abandoned" on the streets of Marseille, at one of their sites. Though there are an estimated 200-300 cave divers in France, less than a dozen are using special mix.

CRPS, 125 Rue Jaubert, 13005 Marseille, France.

A team led by Ken Clayton, 54, Springfield, VA, and Gary Gentile, 42, Philadelphia, PA, conducted a series of three exploration dives, Aug90 to June92, on the *Ostfriesland* (380 fsw/116 msw), a "war prize" sunk by the US Navy in 1921, 72 miles east of Cape Charles, VA. The first two explorations were conducted on heliox, followed by two EAN intermediate mixes and O2 at 20 fsw (6 msw). On the last dive to 340 fsw (104 msw) for a 20 minute bottom time, Clayton utilized a *"pricey"* neox (oxygen-neon) mix. (The neon, which sells for roughly U.S.$2.00+ per cubic foot, was donated by Union Carbide and mixed by The Gas Station, Gloucester, NJ—ed.). This was followed by two EAN intermediate mixes and O2 for a total decompression of about two and a half hours on Hamilton Research tables. Clayton has also experimented with "argox," an oxygen-argon mixture, as an intermediate gas used to maximize helium/ nitrogen offgassing.

K. Clayton, 5908 17th St. NW, Wash. D.C. 20011.

Other reports:

Chris Lazicki, Jim Hegeman, Larry Tucker and John Hall of California, recovered the bell of the *M/V Triple Crown* (260 fsw/78 msw), an oil rig tender that sank in 1962 off the coast of Santa Barbara, CA. The dives were conducted on trimix using BOTH a light commercial surface-*supplied system*, and self-contained scuba..

In Missouri, a cave team of Kurt Olsen, Dave Porter, Mike Hevsack, Doug Chappell and Rodger Gleidt conducted a series of major scooter exploration pushes in *Roubioux Spring, Meremac Spring* and *"Cannonball."* Maximum depths ranged from 145 to in excess of 300 fsw (44-106 msw), with penetrations of 2100-2400 feet..

Greg Stanton, director of the Advanced Diving Program at Florida State University, Tallahassee, FL., reported that FSU held its first trimix course as a part of a graduate-level biology program, the "Grouper Life History Project." FSU has trained over 200 enriched air divers, and is expanding their blending facility to include "nitrox" on-tap, and trimix.

Field Notes

Field Notes

Goodbye Decompression Sickness

Hello Disorders:

A New Approach To Classification

by T.J.R. Francis, D.J. Smith and J.J. W. Sykes,

The current means by which we classify decompression sickness dates back only 30 years to the experience gained during the construction of the Dartford Tunnel in London. Golding et al [1] proposed a system for decompression sickness based upon perceived severity of the cases which arose in the caisson workers employed in the construction of the tunnel. Only symptoms considered sufficiently severe to bring the man [sic] back for treatment were considered to be decompression sickness. They divided the cases into two types: Type 1, or simple 'bends' and Type II, which were more serious or complicated cases which displayed vertigo, shock, paralysis, epigastric pain and shortness of breath. Their system is still in use today essentially unchanged. Traditionally, decompression sickness has been distinguished from the barotraumata and a summary of the current classification of the decompression disorders is presented in T.1.

Traditional Decompression Sickness Terminology

This classification [4] requires the diagnostician to make difficult decisions, particularly where the nervous system is involved. These include determining the location of the lesion (e.g. "cerebral" or "spinal cord") and the mechanism of injury (e.g. "decompression sickness" or "arterial gas embolism"). At a 1991 Undersea and Hyperbaric Medical Society workshop [5] it was recognized that in the great majority of clinical settings, and certainly in the field, such decisions are virtually impossible to make with certainty. Consequently, existing diagnostic

The existing dichotomy between "Type I" or mild decompression sickness (DCS) and "Type II," or serious DCS, is spurious.

"labels" cannot be applied rigorously. As a result, treatment algorithms are inconsistently applied and communication between divers, physicians and medical researchers is compromised.

The existing dichotomy between "Type I" or mild decompression sickness (DCS) and "Type II," or serious DCS, is spurious. Each group contains a variety of conditions with no known commonality of pathophysiology. It is widely recognized that symptoms from the two categories may coexist and that "Type I" may progress to "Type II." *Consequently, the use of these terms is not just confusing, but potentially dangerous if divers are lulled into delaying or failing to report a symptom as a result of using terms such as "pain-only," "mild," "non-serious," or "Type I."* These terms also lack any inherent meaning, they have to be learned. Consequently, communication with medical personnel who have not been indoctrinated into their use is difficult. Decompression disorders are potentially highly dynamic conditions, yet the terminology currently used takes no account of this. This dynamic quality (e.g. progressive or relapsing) may be a better index of the urgency of a case than whether it is "Type I" or "Type II."

The main reason why the existing classification has been retained is that its use has been made seductive. Treatment tables have been applied, more or less as a reflex, depending upon whether the "diagnosis" is "Type I," "Type II," or "AGE" (arterial gas embolism). Fitness to return to diving (or aviation) has been based upon the same, arbitrary, diagnostic categories. *This has resulted in patients being shoe-horned, occasionally with much difficulty, into these artificial and very limited groups more for administrative convenience than as a true reflection of what is wrong with the patient.*

It was concluded at this workshop, that the present system of classification based on medical cause should be abandoned and that a descriptive definition of the decompression disorders be adopted. The workshop proposed that the current terms: Decompression sickness "Type I," "Type II" and Arterial Gas Embolism be abandoned in favor of the term "Decompression Illness," or DCI, which, for terminology purposes, is modulated by terms that describe the evolution and manifestations of the disease.

The protocol consists of a matrix which provides a formalized *aide memoir* for data collection and from which a terminology has been derived that can be used to describe a wide variety of decompression conditions. The following key information is required to describe a case of decompression illness adequately: the evolution of the case; clinical manifestation(s); the time to onset of each manifestation; the gas burden and whether there is evidence of barotrauma. Additional important information includes: the response to recompression and the results of any investigations. A summary of this system is in Table 2 and definitions are provided below.

T.1: Traditional DCS & AGE Classification**	T.2: Descriptive Definition of Decompression Disorders
DECOMPRESSION SICKNESS	**ACUTE DECOMPRESSION ILLNESS**
TYPE I	A. EVOLUTION
1. MUSCULOSKELETAL (including 'niggles')	1. Progressive
2. CUTANEOUS	2. Static
a. Transient pruritus	3. Spontaneously Improving
b. Circulatory manifestations (Cutis Marmorata)	4. Relapsing
3. LYMPHATIC	B. MANIFESTATION(S)
4. MALAISE/ANOREXIA/ FATIGUE	1. Pain
TYPE II	a. Limb pain
1. PULMONARY	b. Girdle pain
2. NEUROLOGICAL	2. Cutaneous
a. Spinal cord	3. Neurological
b. Cerebral	a. Audiovestibular
c. Cranial nerve	4. Pulmonary
d. Labyrinthine disturbance (inner ear DCS)	5. Lymphatic
e. Peripheral nerve	6. Constitutional
f. Migraine-like symptoms	C. TIME OF ONSET
g. Girdle pain	D. GAS BURDEN
3. HAEMOCONCENTREATION AND HYPOVOLAEMIC SHOCK	E. EVIDENCE OF BAROTRAUMA
BAROTRAUMA	**BAROTRAUMA**
A. PULMONARY	A. PULMONARY
1. Mediastinal emphysema	1. Mediastinal emphysema
2. Pneumothorax	2. Subcutaceous emphysema
3. Arterial gas embolism	3. Pneumothorax
B. OTOLOGICAL	B. OTOLOGICAL
1. External Ear Canal	1. External ear
2. Middle Ear	2. Middle ear
3. Inner Ear	3. Inner ear
C. PARANASAL SINUS	C. SINUS
D. DENTAL	D. GASTROINTESTINAL

**Elliot & Kindwall [2] and Farmer [3]

Evolution of DCI

The evolution of a case refers to the development of the condition *prior to recompression*. This information is best recorded as the case evolves. Because DCI is frequently dynamic, the evolution may change from one observation to the next. Thus, a condition that initially presents as being *"progressive,"* as the patient becomes increasingly aware that something is wrong, may stabilize so that it can then be described as *"static."* The patient may subsequently undergo a substantial improvement, occasionally to the extent of a complete resolution of symptoms. This can be described as *"spontaneously improving."* Occasionally, the symptoms return or new symptoms appear, in which case the condition would be described as *"relapsing."*

A condition may be described as *progressive* if the number or severity of symptoms or signs increases—e.g. limb pain that becomes increasingly severe, or involves more sites, or a neurological presentation in which the loss of function becomes more profound or extensive. The development of a new manifestation, such as a neurological symptom or sign in addition to limb pain, also represents progression of the condition. Additional description may also be useful such as whether the progression is rapid or slow.

If the condition is not changing substantially, it is *static*.

It is common for a number of presentations of DCI to improve without recompression. Sometimes this may be to the point of apparent recovery, although this may only be transient. Because the intensity of DCI symptoms can fluctuate, substantial improvement must occur to apply the term *spontaneous improvement.*As with other terms describing a case's evolution, this should only be used to describe events prior to recompression.

Occasionally, cases that have improved spontaneously undergo a secondary deterioration, or relapse, particularly with some neurological manifestations.When a condition gets worse in the absence of any spontaneous improvement, it should be described as *progressive*.

DCI Manifestations

Pain is probably the most frequent manifestation of decompression illness. It describes the deep aching pain in or around one or more joints which may begin during decompression or after completion of a dive. Unlike the pain of musculoskeletal injury, limb pain decompression illness is generally not exacerbated by movement of the affected joint. The pain may range from mild, barely detectable discomfort to a steady, boring, nearly unbearable pain. Limb pain should be distinguished from "girdle pain." This is a poorly localized, aching or "constricting" sensation which is generally in the abdomen, pelvis or, occasionally, in the chest. Girdle pain in the context of decompression illness is generally considered ominous since it is frequently a harbinger of neurological deterioration.

Involvement of the nervous system may be subtle, multifocal and very difficult to localize. A number of different mechanisms may be involved in the development of the pathology of these neurological conditions, so it is important that the terminology presumes neither a location or a mechanism. Neurological involvement can be broken down into the loss of certain functions: higher functions, which would include aberration of thought processes or affect, loss of memory, difficulty talking etc.; alteration to the level of consciousness, including seizures; loss of coordination, strength or sensation; dysfunction of special senses; loss of bladder control or anal function.

Involvement of the audio-vestibular system is a distinct syndrome within the neurological category that consists of vertigo , tinnitus (ringing in the ears), nystagmus (jerking movements of the eyes) and loss of hearing after a dive. Nausea and vomiting may accompany these symptoms but, of themselves, are not sufficient to imply audiovestibular involvement. Again, more than one mechanism may be responsible for this manifestation, and it may be very difficult, without

The main advantage of this system is that it contains no guesswork with respect to either the mechanism or the anatomical location of the disease process . . . It does not require that the first person to attend the patient have a great deal of experience or expertise to use it properly.

elaborate investigation, to determine the site of injury. However, if a cause can be established, such as round window rupture, then the more specific diagnosis should be made.

Pulmonary involvement in DCI may be resultant of two quite distinct processes: lung rupture due to barotrauma and the cardiopulmonary consequences of massive venous gas embolism. Although the mechanisms involved are distinctly different, it may be difficult for lay personnel to distinguish between them initially, because many of the symptoms and signs are shared. However, modern diving practices result in pulmonary DCI due to the latter mechanism very rarely indeed. The symptoms or signs that imply pulmonary involvement in decompression illness include chest pain, cough, haemoptysis (coughing up blood or blood-stained sputum), shortness of breath, cyanosis (blueness or duskiness of the skin, lips or mucuous membranes), pneumothorax (gas trapped in the pleural space in the chest), subcutaneous emphysema ("crackling" under the skin) of the neck and, occasionally, voice change. When describing pulmonary decompression illness, it is important to note whether clinical or radiological evidence of pneumothorax or mediastinal emphysema exists as this is known to be a consequence of lung rupture.

The skin may be affected by diving in a number of ways. Two very common manifestations of decompression, which are not generally regarded as illnesses, are suit "squeeze" and itching in the absence of a rash. The term cutaneous DCI should be used to describe the condition that generally presents with severe itching around the shoulders or over the trunk which, after a time, develops into an erythematous rash and which may progress to blue-ish mottling or marbling of the skin. When further describing the condition, it is desirable to describe the location of the disorder.

Lymphatic DCI may be used to describe cases in which there is painful swelling of individual or discrete groups of lymph nodes or rare cases where there is extensive edema of one or more limbs.

A number of non-specific symptoms can occur after diving which, if severe or if accompanied by other manifestations, may be considered part of the DCI syndrome. These constitutional symptoms include headache, fatigue, malaise (which may include nausea and vomiting) and lack of appetite.

Very rarely, other manifestations of decompression illness may occur. Such conditions should be described using appropriate medical terminology.

Other Significant Data

The time of onset can provide a great deal of information to medical personnel regarding mechanisms of disease and, possibly, the outcome of some cases. Following hyperbaric exposures, this should be the time from reaching the surface to the onset of the manifestation. If the manifestation occurs during ascent it should be recorded as such.

The gas burden is an estimate of the residual inert gas load present on surfacing. At present, recording the dive profile is the most useful index available.

Clinical or radiographic evidence of barotrauma should be documented, particularly where there are pulmonary or audiovestibular manifestations. Where there is such evidence, the barotraumata are diagnosed as before.

To complete an accident record, it is important to record the outcome of recompression and the results of additional clinical investigations.

The Language of DCI

Lengthy descriptions are unwieldy for communication purposes, and an abbreviated label is needed until the natural syndromes are identified. The proposed new form for describing a decompression disorder is as follows (see T.2):

Acute, [Evolution Term], [Manifestation Term(s)], Decompression Illness

In this case, the term "acute" distinguishes the conditions described above from the possible chronic consequences of decompression, such as osteonecrosis (bone necrosis). The phrase decompression illness (DCI) incorporates the familiar terms decompression sickness and arterial gas embolism. The appropriate evolution term, is used exactly as defined above.

"Acute progressive limb pain and neurological decompression illness presenting 20 minutes after surfacing with a moderate gas burden and no evidence of barotrauma."

The number of manifestation terms which are used will depend both on the condition and the context in which the terminology is employed (see T.2). In a condition with only one or two manifestations, it is appropriate to use those that apply, for example, "acute static, cutaneous and neurological decompression illness." In complex cases it may be appropriate to use the term "multisystem."

The amount of detail in the description depends on the purpose for which the terminology is being used. As a diagnostic label, the above terminology should suffice. Frequently more information is needed, such as during the transmission of information over the telephone or radio during a consultation. In this situation, the three additional key pieces of information—the time on onset, the gas burden, and any evidence of barotrauma—can be added. These are likely to be valuable in discriminating between the various syndromes. An example of such a brief report is:

"Acute progressive limb pain and neurological decompression illness presenting 20 minutes after surfacing with a moderate gas burden and no evidence of barotrauma."

For treatment reports and database purposes a more detailed report is likely to be necessary.

The main advantage of this system is that it contains no guesswork with respect to either the mechanism or the anatomical location of the disease process. Furthermore, it employs terms that are readily understood within the medical community. It does not require that the first person to attend the patient have a great deal of experience or expertise to use it properly. Communication between divers and non-diving medical personnel will be facilitated by its use, because all the terms have inherent meaning. *However, basic instruction is critical for the system to be used properly.* Such instruction is made relatively simple because there is no need to brain wash people to accept untenable rules and assumptions. This system permits the description of a dynamic, changing condition without difficulty.

We have been unable to classify decompression illness reliably to date, which has limited our progress towards understanding these intriguing conditions. It is hoped that by using a readily understood descriptive terminology, consistent and accurate 'diagnoses' should now be possible, which will improve the management of cases. More importantly, if these data are then collected and collated, the natural syndromes associated with decompression will become readily apparent. If we learn what the natural syndromes are, we will be able to direct our efforts more effectively towards preventing decompression illness more effectively in the future.

Surgeon Commander James Francis studied medicine at St. Thomas' Hospital Medical School in London, qualifying in 1977. Following the rapid onset of disillusionment with the National Health Service, he joined the Royal Navy. After gaining a Master's degree in occupational medicine in 1982, he served at the Institute of Naval Medicine (INM), initially researching trench foot, which afflicted the marines in the Falklands conflict. He then went on to study diving medicine, and in 1985, served as an exchange medical officer to the Naval Medical Research Institute in Bethesda, Maryland, where he completed four years of research on the mechanisms involved in neurological decompression illness. This work formed the basis for his Ph.D thesis, the degree being awarded in 1990. He is currently the Senior Medical Officer (Diving Medicine) at the Institute For Naval Medicine, Alverstoke, Gosport, Hampshire, PO12 2DL. Fax#: 0705.504.823.

More information...

1. Golding, F.C., Griffiths, P., Hempleman, H.V., Paton, W.D.M. and Walder, D.N. (1960) Decompression sickness during the construction of the Dartford Tunnel. Br J Med 17, 167-180.
2. Elliott, D.H. and Kindwall, E.P. (1982) Manifestations of the decompression disorders, in: Bennet, P.B. and Elliott, D.H. (eds.) The physiology and medicine of diving, 3rd. edition. Balliere Tindall, London, pp. 461-472.
3. Farmer, J.C. (1990) Ear and sinus problems in diving, in: Bove, A.A. and Davis, J.C. (eds.) Diving Medicine, 2nd edition. W.B. Saunders, London, pp 200-222.
4. Gorman, D.F. (1991) A proposed classification of the decompression illnesses, in: Francis, T.J.R. and Smith, D.J. (eds.) Describing decompression illness, 42nd Workshop of the Undersea and Hyperbaric Medical Society, Bethesda, MD, pp. 6-9.
5. Francis, T.J.R. and Smith, D.J. (eds.) (1991) Describing decompression illness, 42nd Workshop of the Undersea and Hyperbaric Medical Society, Bethesda, MD.

Accepting new terminology for decompression disorders.

R.W. Hamilton

The article by James Francis and colleagues proposes a new lexicon for discussing decompression-related disorders as developed by a high-level workshop of the leading experts in decompression problems. The proposed method recognizes that the underlying pathology of most such problems cannot be diagnosed in the hospital, let alone in the field, and defines a descriptive approach to classification to replace the older terms. It lumps the familiar "decompression sickness" and "embolism" into a single category of "decompression illness." The main problem being solved by this change is that epidemiological studies are next to impossible to use when the diagnosis in a medical report is limited to something such as "decompression sickness Type II," which tells nothing about the patient's symptoms and condition. The new method describes the condition in terms of its evolution, the observed signs and symptoms, the time of onset, the gas loading or burden, and evidence of lung barotrauma. Another thing that should be on this list and always be documented is the response to recompression.

As defined here "decompression illness" comprises two categories, those which are caused by the presence of decompression-induced gas phase within the body, the other by mechanical damage to or by gas- filled spaces such as the middle ears or lungs. Although not mentioned by Francis and colleagues, those conditions related to gas phase or gas bubbles are a subset of a more general disorder called "gas lesion disease." This includes decompression illness and also systemic gas embolism due to mechanical factors occurring without a gas loading or change of ambient pressure; these can be caused by such as surgery, stab wounds, etc. The conditions defined by Francis et al. as "barotrauma" can themselves cause a confusion in terms when used improperly. Barotrauma is injury due to pressure. The term "pulmonary barotrauma" is often used synonymously with cerebral arterial gas embolism. The flaw here is that the disorder is a brain and not a lung problem; pulmonary barotrauma is the cause of the disorder, not the disorder itself.

Better descriptions are important and needed, and it is no great loss to get rid of the non-descriptive terms "Type I" and "Type II." It is worth noting that these are categories intended only to specify the treatment, not to define the disease. Although treatment itself is not a part of the new description, the new protocol has an impact on treatment options; the 6-atm recompression with air or enriched air of Table 6A is likely to be discontinued as evidence accumulates that it offers no real benefit over the 100% oxygen at 2.8 atm of Table 6 (many experienced treatment centers, however, still swear by the 6-atm recompression). There are still cases that can be treated adequately with the shorter Table 5 when used promptly and when neurological involvement can be clearly ruled out, but liability concerns are causing this one to disappear from the hospital and commercial worlds. The new terminology needs to provide a field-useable algorithm for making this selection.

While the clinical presentation should follow the use of "decompression illness" as recommended, it still seems proper to refer to the disease which we hope to prevent by reliable decompression tables as "decompression sickness." This, DCS, is a systemic condition caused by the removal of dissolved gas from solution because pressure is reduced too quickly. Although the distinction is not crystal clear, in general the table has only a small role to play in the other decompression disorders that are not specifically decompression sickness. Embolism for cause barotrauma for example might not be decompression sickness and need not be scored as such. Decompression sickness is not an accident; a certain incidence of it is expected from practical diving.

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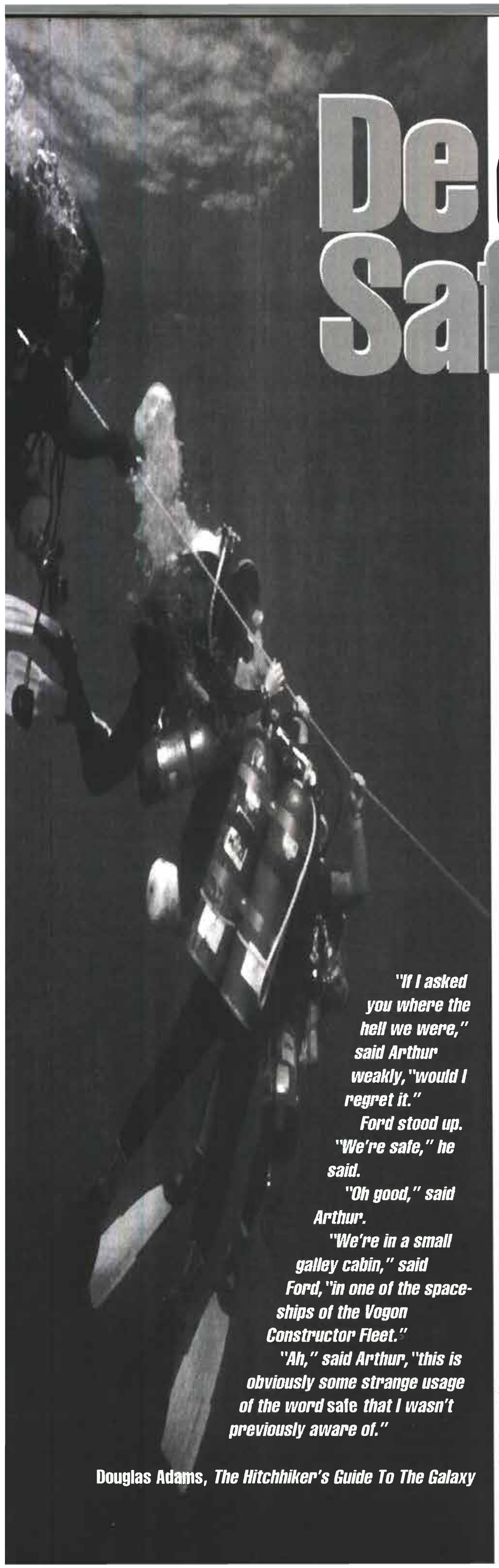
Decompression Safety

by Richard D. Vann



"If I asked you where the hell we were," said Arthur weakly, "would I regret it."
Ford stood up. "We're safe," he said.
"Oh good," said Arthur.
"We're in a small galley cabin," said Ford, "in one of the spaceships of the Vogon Constructor Fleet."
"Ah," said Arthur, "this is obviously some strange usage of the word safe that I wasn't previously aware of."

Douglas Adams, *The Hitchhiker's Guide To The Galaxy*

Photo by: Bret Gilliam

Safety, in an ideal world, is freedom from risk. Unfortunately, real-world activities such as diving have risks that are unavoidable. These activities are defined as "safe" when their risks are judged to be acceptable.

Consider the risk of decompression illness (DCI) after a 60 minute no-stop air dive. If the dive were conducted at 10 fsw (3 msw), no one should develop DCI. On the other hand, it is probable that everyone would be "bent" if the dive were conducted at 150 fsw (45 msw). Between these extremes, is a dive with a DCI incidence that we might chose to define as acceptable. This dive is "safe" by definition, even if DCI occurs occasionally. If we decide the dive is not safe enough, a lower acceptable risk could be chosen.

There is a difference between DCI risk and DCI incidence. Incidence refers to the results of actual dives, that is, the number of DCS incidents divided by the total number of dives. Risk, on the other hand, refers to the DCI incidence that would occur if the same dive profile was conducted an infinite number of times— a theoretical probability. It is important to distinguish between risk and incidence, because incidence often refers to actual exposures with different depth-time profiles.

Establishing what is "safe" is a three-part process. First, the potential injuries must be identified; second, the risk of developing these injuries must be related to the exposure; and third, an acceptable level of risk must be chosen. This is an information dependent process that, for diving, requires exposure data from experimental or actual dives. At present, the most useful data comes from experimental dives in hyperbaric chambers where depth, time, and dive conditions are carefully controlled, and divers can be questioned closely for the presence or absence of symptoms. Current field data is of limited value except for providing information on diving accidents. By using dive computers to record depth-time profiles, data from actual dives may someday be of great value.

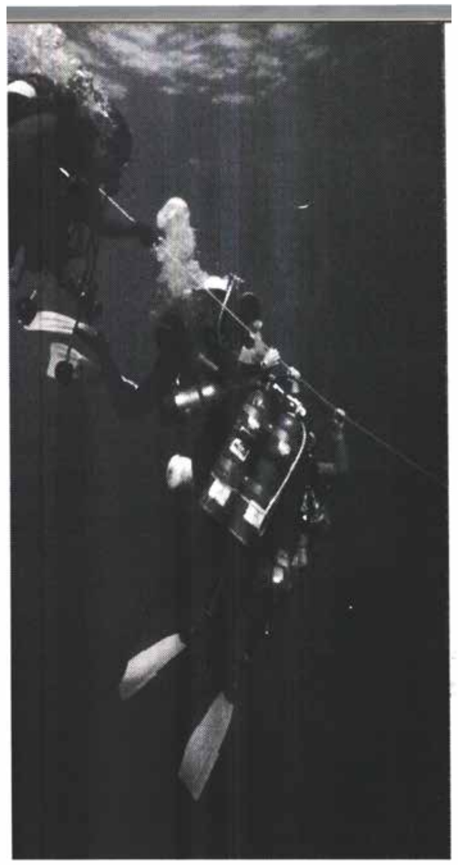
A partial list of acute DCI injuries includes itching, pain, numbness, weakness, cerebral dysfunction, paralysis, chokes, and death. Death is rare today except for an occasional blow-up or missed decompression. Of the other complaints, pain-only DCI is the most common report during experimental diving while mild neurological DCI (numbness and weakness rather than paralysis) is most commonly reported by sport divers.

This difference is important to understanding decompression safety, but the reasons for it are uncertain, and a number of explanations are possible. (1) Minor symptoms are often unrecognized or ignored, and resolve without treatment. Sport divers may not report some minor symptoms while experimental divers are trained to report even the most trivial. (2) Treatment delays are shorter for experimental divers than for sport divers, and DCI pain has an earlier onset than mild neurological symptoms. (Severe neurological symptoms are of rapid onset.) Early treatment may forestall the onset of some mild neurological symptoms in experimental divers. (3) Multilevel and repetitive exposures are more common in sport than in experimental diving. These exposures may predispose sport divers to mild neurological symptoms. (4) DCI in sport "applications" is often associated with violations of accepted diving procedures.

Sport diving currently provides little data that can teach us how depth and time affect DCI risk. A guess at the overall risk is about 0.02% (one DCI incident in 5,000 dives), however, with the exception of technical diving, most sport dives are well short of the no-stop exposure limits with part of the time spent at shallow depths.

Currently much more information is available about experimental diving. There have been thousands of wet, working chamber exposures for which the depth-time profiles and presence or absence of symptoms have been carefully documented. This data has used to develop statistical decompression algorithms that are quite different from the better-known deterministic models (e.g., the Haldane model and it's derivatives). While deterministic models often account for dives resulting in DCI, statistical algorithms are able to use all the data that is available, with or without DCI, and are able to estimate decompression risks for any dive profile. Statistical algorithms will someday permit divers to chose whatever DCI risk they consider to be acceptable.

Using statistical algorithms based primarily on "pain-only" DCI, the U.S. Navy no-stop exposure limits for air diving have estimated DCI risks of about 1-4%. At 60 fsw, for example, a 60 min dive has a risk of about 2% while a 30 min dive has a 1% risk. How accurate are these estimates? Risk estimates for dives with the most testing—typically those clustered around the no-stop limits— have the greatest accuracy. Estimates for shorter or much longer dives, where there has been little or no testing, are less accurate.



Statistical modeling is a powerful tool but requires extensive data for accurate risk estimation. Experimental diving programs can provide only limited data, and present research funding is shrinking. A promising way to improve our understanding of DCI risk is to accurately record field profiles using computers/profilers supplemented with accurate information on symptom incidence.This may allow us to assess the influence of age, weight, gender, etc. on DCS risk. In particular, we need data on dives believed to be safe, such as 30 min. at 60 fsw (18 msw), but unconfirmed by existing data. Until such data is available, our knowledge of decompression safety will remain insecure.

What is acceptable DCS risk? Must sport divers accept DCI risks of several percent if they dive to the full extent of the no-stop limits or beyond? While additional data is needed for confirmation, objective analysis of existing data suggests this may be the case. And who should be the one to choose acceptable risk; the diver, a computer company, or an independent body? These are questions for the future. Like the old Chinese cliche, we live in interesting times.

Given the limited state of our current knowledge, what conclusions can be drawn regarding decompression safety? First, a small incidence of decompression illness is unavoidable. Divers should be prepared for DCI and have a plan to deal with it, including having an evacuation and treatment plan, ample onsite oxygen supplies, and "current" diving accident insurance.

Second, is the realization that there is inadequate information on the DCI risks inherent in existing dive tables and computers, and consequently, these tools should be used conservatively. Ultimately, the uncertainties surrounding decompression safety may be clarified by extensive study of actual diving habits and outcomes. As this data becomes available, the associated tables and computers will permit the choice of acceptable risk.

> Divers should be prepared for DCI and have a plan to deal with it, including having an evacuation and treatment plan, ample onsite oxygen supplies, and "current" diving accident insurance.

Richard Vann, PH.D is the director of Applied Research at the Hypo/Hyperbaric Center, Duke University, and the Director of Research for the Divers Alert Network. He can be contacted at: Box 3823, Duke Medical Center, Durham, NC 27710. Fax: 919-684-6002

The Chaotic Nature of Decompression: A "Non-Haldanian View"

by Michael Powell

The concept of *chaos* sharply contrasts with the considerably older notion of "deterministic predictability" that forms the basis of modern computational decompression theory.

Deterministic predictability refers to the ability to accurately predict the course of events from the knowledge of initial conditions and traces its origin to the "mechanistic" view of the universe originally advanced by Sir Isaac Newton and the French mathematician LaPlace. It was this mechanistic view of the world that prompted the French philosopher Descartes to write, *"Give me matter and motion, and I can describe the universe."* Recent advances in our understanding of complex systems have fundamentally changed this notion of the world. Systems that were once thought to be simple and predictable (such as the motion of the planets) are now viewed as exceedingly complex (Gleick 1987).

There does not seem to be a universally accepted definition of the term chaos. The commonly used sense of the word implies a total randomness; but not quite. Chaos can describe systems that possess long term temporal stability, often for millennia, oscillating about a single fixed point or *attractor.* Technically, chaos refers to irregular or apparent randomness that arises even in the absence of environmental perturbations ("noise") in deterministic systems. While a system may be deterministic, nevertheless, it is often impossible to predict its dynamics as a function of time to any great degree; any change in initial conditions, no matter how small, can lead to another path.

The description of dissolved gas transport is popularly viewed as a relatively straight forward process of the movement of inert gas molecules by diffusion and their conveyance by the blood stream. However, because of the complexity of the human body, it is becoming increasingly recognized that the process is very involved, and models must make many assumptions about the structures of the body. This includes both how structures are organized and the minute-to-minute variations in regional blood flow. Regrettably, biological systems are neither that simple nor regular.

Chaos and Determinism: Two World Views

We generally imagine that the world is made up of many little effects which channel to produce some larger effect, sometimes salutary and sometimes adverse. We know that breaking a shoe string can cause us to be late for the bus, or conversely, leave home late and avoid a disastrous traffic accident. In the body, as in all living and non-living systems, little conditions can sometimes have great consequences. Scientists have termed this condition *chaos.*

In 1963, the meteorologist Dr. Edward Lorenz published what was to become a classic paper, *"Deterministic Nonperiodic Flow"* (1963) in which he described systems, later termed "chaotic," not unlike the problem of long-range weather forecasting; he proposed that such forecasts were virtually impossible. Contemporary thought held that complete knowledge of all meteorological variables (wind velocity, direction, humidity, barometric pressure, etc.) would permit the forecasting of atmospheric events several months into the future. Lorenz described his observations taken from a simple computer model of a meteorological system; surprisingly, when the computer was called to reproduce the original forecast, it was found to depart significantly after a short period of time. The cause of this was traced to very minor differences in the initial input on the repeated trial — the computer had rounded off a variable from six decimal places to three. This phenomenon of "sensitive dependence on initial conditions," later addressed by Dr. Lorenz in a December, 1979 talk,*"Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off A Tornado in Texas?"*, has often been termed "the butterfly effect."

Chaotic effects, where by *small changes in initial conditions* result in large changes at a later time have been discovered in many social, physical, and biological systems including the price of cotton, the batting of a baseball, vortices in a stream, swirls in a rising column of smoke, cars clustering on a highway, and in gas phase transitions.

Chaos and Decompression Tables

Well-behaved Haldanian systems form the basis for calculating most decompression tables. The are immutably regular, and the underlying system is assumed to possess the following general properties:

1. They are deterministically predictable,
2. Blood flow is continuous through all scale dimensions,
3. No gas phase separation exists before, during, or after decompression(s),
4. The differential equations that describe all aspects of the phase transitions are linear, and,
5. It is always possible to safely perform infinite cycles of compression/decompression about the original attractor (starting conditions).

These assumptions are in contrast to the real world "chaotic" system of the body, wherein small differences are often of prime importance and whose characteristics are that:

1. It is deterministic, but it is not predictable,
2. Blood flow does not display the same characteristics through all scale dimensions,
3. Limited tissue gas phase separation is to be expected,
4. Nonlinear differential equations describe this gas phase separation, and
5. The system can suddenly switch during a compression /decompression cycle to a new attractor; after extensive compression/decompression cycles, numerous (local) attractors may have arisen leading to an incomplete knowledge of the final state.

Thus, a gas bubble that forms in a tissue during the first decompression may be semistabilized and represent a new source and sink of tissue gas within a microregion with each additional compression/decompression cycle. These new sources and sinks modify, often greatly, the gas flux and bubble growth dynamics in that microvolume. Tissue gas flux in the region would then tend to depart deterministically, but unpredictably, from the well-ordered and fully deterministically predictable systems envisioned by Haldanian analysis. This would naturally make repetitive (or dives with long decompression periods) increasingly harder to predict with respect to a "bends-free" outcome.

Let's examine the problem of decompression from two vantage points, one of blood flow and the other of gas bubble formation. We shall see how these add a large measure of uncertainty to the decompression process. If we were to try to model these events with respect to decompression-induced gas phase formation, it would require greater degrees of precision and processing power than is available in the foreseeable future.

Blood Flow

The exchange of gases between the blood and the cells of the body occurs in the very fine capillaries. One of the characteristics of capillary blood flow, is the unevenness of microperfusion over time. The physiologist Krough, was the first to describe the nonconstant flow, in 1918, noting that the precapillary sphincters (muscular "doors") opened and closed in an apparently random fashion. This unevenness in blood flow leads to a change in gas uptake or elimination in tissue microvolumes.

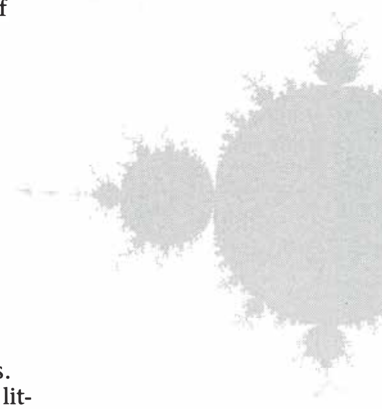
Blood flow in the Haldanian model is temporally homogeneous. Zero flows are not considered as a lower boundary condition. Capillary blockage by gas bubbles likewise does not enter the calculations, since this model implicitly assumes that all of the inert gas remains dissolved in all phases of the dive. Decompression illness is assumed to represent a breakdown of the paradigm.

Gas Phase Formation

In 1966, Dr. Brian Hills was the first to emphasize the variability of the transition point from the dissolved to the gaseous phase of the inert gas in supersaturated tissue. His concept, which involved programming for the lowest stable energy state (the "thermodynamic model"), was in contradistinction to the ideas originally advanced by the trio of Boycott, Damant, and Haldane in 1908, who portrayed a system possessing chemical potential energy, a "metastable limit" or a "boundary concentration" below which a gas phase would not form.

Contemporary decompression tables are calculated with the direct assumption that a gas phase virtually never forms. Decompression illness resulting from tissue bubble formation is an abnormality or "failure of the table" to perform as expected. Some divers even regard the process as a failure of themselves to decompress properly, conjecturing that some procedural "fault" lies with them. While it is widely known that 'subclinical' gas phases do form in the body during decompression, these are not considered in the Haldane model, even conceptually. Variations in individual response to decompression is generally ascribed to biological or physiological dissimilarities. A chaotic concept accepts variability no matter how similar the individuals or conditions might seem.

The postulated nonlinearity of phase transition equations gives a different view of decompression under the "chaotic concept." Chaotic systems are deterministic; they rigidly follow physical laws and often allow the prediction of events for a short time into the future. Thus the Haldane model is successful for short decompressions or one or two repetitive dives, however it begins to break down when extrapolated to longer and longer times (one is eventually forced into saturation decompression schedules that most likely treat all but the severest of deviations.)

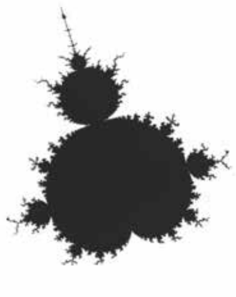


The following summary highlights some of the complexities in trying to quantify gas uptake and elimination during the compression/decompression process. One can but little wonder that you can acquire a case of the "bends" even if you do everything with punctilious perfection.

1. Inert gas enters tissue microvolumes at rates commensurate with local blood flow in that microregion. This local blood flow (in cartilage of the knee, for example) is determined by local factors such as muscular activity, local tissue oxygen needs, as well as more global factors such as general heart rate (cardiac output) and central nervous system control. While total organ blood flow is important ("tissue half-times" are classically described by the quantity of flow); it is the time-varying capillary flow that determines the gas uptake and elimination flux at a micro level. This flow is not exactly predictable.

2. During decompression, cardiac output and central nervous system control are the general determinant of organ flow, but it is local perfusion that will determine the gas elimination rate for the microvolume. Local perfusion rates can periodically become reduced and the local ratio of P_{inert} to $P_{ambient}$ can increase such that supersaturation results, and new gas bubble formation occurs and/or micronuclei grow.

3. Decompression tables are designed to keep the local tissue inert gas supersaturation ratios small during decompression thus globally favoring the inert gas to remain in the dissolved state, however local situations (e.g. physical tension produced by muscle exercise) insure that all of the gas will not be dissolved in virtually every decompression situation. Situations of protracted decompression (e.g., from deep depths or multiple repetitive decompressions) will also favor the appearance of at least a small degree of gas phase generation. Because of sensitive dependence on initial conditions, the guarantee of a gas-phase-free decompression is generally not possible.



4. The localized tissue gas bubble accumulations will shrink or grow commensurate with several factors. These include:

(a) local loss of dissolved inert gas to the circulatory system (perfusion "sinks"),
(b) diffusion of dissolved inert gas into the microbubbles, or
(c) Boyle's law effects.

During the period(s) in which the gas phase is present, organic compounds may reduce surface tension by adsorption on the bubble-liquid interface. If they adsorb more easily than desorb, they will tend to stabilize bubbles against shrinkage.

5. Some gas from the first dive might participate in the events of the following dive. By placing the system in a second compression/decompression cycle, depending upon the length of the surface interval, a portion of the gas phase formed in the first cycle, particularly if it is extravascular may participate in the gas uptake (compression) cycle once again. The gas nuclei, formed during the decompression phase, now act as new sources or reservoirs of inert gas in addition to that introduced by local capillary profusion. If not completely destroyed by the compression, they will also serve as "seed nuclei" during the subsequent decompression. These "virtual tissues" are generally handled mathematically by extending tissue compartment half-times.

6. Since gas phase formation and/or growth is not instantaneously initiated with decompression, an indeterminate amount of gas can be separated at any point in time following pressure reduction. While the inert gas remains dissolved, the driving force for its elimination is greatest. Tissue gas elimination during surface intervals in repetitive dive situations is calculated on the assumption that all of the tissue gas is dissolved, and is not acting as gaseous "sinks." Clearly, since the time and degree of gas phase formation is not readily determinable, a high degree of uncertainty exists about the initial conditions in the tissue at the start of the next compression. Under these conditions, long surface intervals can present at least as many opportunities for gas phase separation as short ones.

7. Since some of the gas nuclei formed following the previous decompression were the result of deterministic but quite unpredictable events, the system will enter the new compression/ decompression cycle in an indeterminate state. The actual tissue gas loads, in terms of number of moles of gas, is largely unknown in the repetitive condition(s). Time dependent gas phase separation and growth introduces considerable uncertainty into the actual state of the system. It is therefore not possible to categorically state, for example, that repetitive dives performed with longer surface intervals (when all gas is presumed to be in a dissolved state and the surface interval credit table is calculated to reflect this) will be safer than those with shorter surface intervals.
One can easily visualize that either repetitive cycling, or protracted decompression, can introduce real local variations to the calculated, global description of the state of the system. Mathematically this is accounted for by extending compartment half-times which are not necessarily in accordance with either realistic diffusion or perfusion limits.

8. No degree of increased precision in the half-times of their associated M-values will render a chaotic system completely deterministically predictable (The parallel was first noted by Lorenz in his meteorological model). It follows that repeated or protracted (long decompressions) cycles can result in an increased probability of decompression illness, though not through any fault of inaccuracy of limiting values employed in deterministic Haldanian models.

9. To avoid these additive problems, it is necessary to "reset" the system, effectively allowing it to oscillate about its original starting point (sea level saturation with minimal tissue micronuclei) in order to insure a good prediction.

Despite the advances that have been made in decompression research, we are still quite limited in our understanding of the process. Recognizing the inherent "chaotic" nature of the decompression, statistical-based methods provide a fruitful avenue to pursue in the future.

Dr. Michael Powell received his doctorate in biophysics from Michigan State University. He began work in underwater physiology at Union Carbide in 1969, under Dr. R.W. Bill Hamilton, and went on to research the use of Doppler flowmeters in the study of decompression illness with Dr. Merrill Spencer. Powell currently heads the Environmental Physiology/ Biophysics Group at the NASA Lyndon B. Johnson Space Center. He can be contacted at: NASA Lyndon B. Johnson Space Center, Environmental Physiology/Biophysics Section, Houston, TX 77058.

More information...

Bert. P. Barometric Pressure. Undersea Medical Society, Bethesda, MD (1978).
Boyle, R. New pneumatical experiments about respiration. Philos. Transact., 5, 2011(1670).
Boycott, A.E.; G.C.C. Damant; and J.S. Haldane. The prevention of compressed air illness. J. Hyg. Camb., 18, 42 (1908).
Elliott D.H, Kindwall E.P. (1982). Manifestations of the Decompression Disorders. In: Physiology and Medicine of Diving, 3rd Edition. Eds. Bennett PB, Elliott DH. Bailliere Tindall, London.
Ferris, E. B.,Jr.; and Engel, G. L. The Clinical Nature of High Altitude Decompression Sickness. In: Decompression Sickness. Ed. J. F. Fulton. Philadelphia. Saunders (1952).
Gillis, M. F.; M. T. Karagianes; and P. L. Petersen. Bends: detection of circulating gas emboli with an external sensor. Science, 161, 579 (9168).
Harvey, E. N. Physical Factors in Bubble Formation. In: Fulton, J. F., ed. Decompression Sickness. Philadelphia, Saunders (1951).
Powell, M. R.; M. P. Spencer; and O. von Ramm. Ultrasonic Surveillance of Decompression. In: Physiology and Medicine of Diving, 3rd Edition. Eds. P. B. Bennett and D. H. Elliott. Bailliere Tindall, London (1982).
Spencer, M. P., and Campbell, S. D. Development of bubbles in venous and arterial blood during hyperbaric decompression. Bull. Mason Clinic., 22 (1), 26 (1968).
Spencer, M. P. Decompression limits for compressed air determined by ultrasonically determined blood bubbles. J. Appl. Physiol., 40,227 (1976).
Vann, R. D. Decompression Theory and Applications. In: Physiology and Medicine of Diving, 3rd Edition. Eds. P. B. Bennett and D. H. Elliott. Bailliere Tindall, London (1982)

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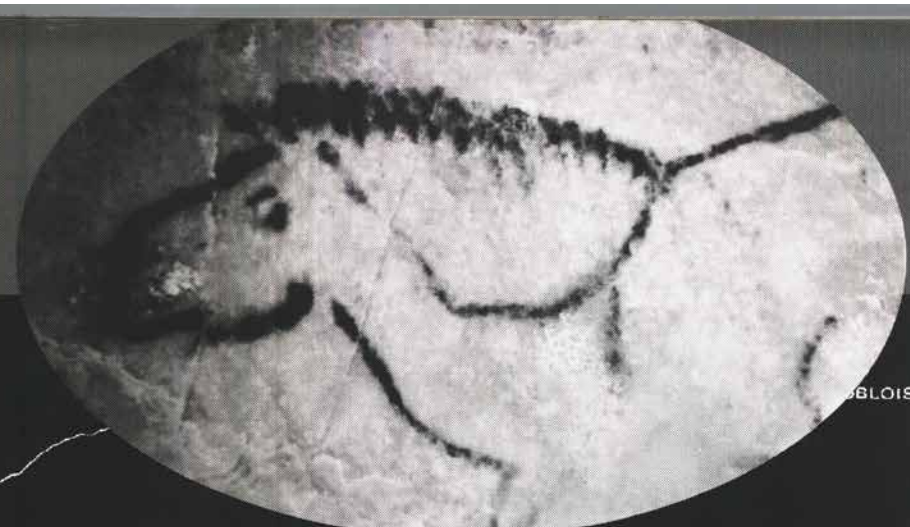
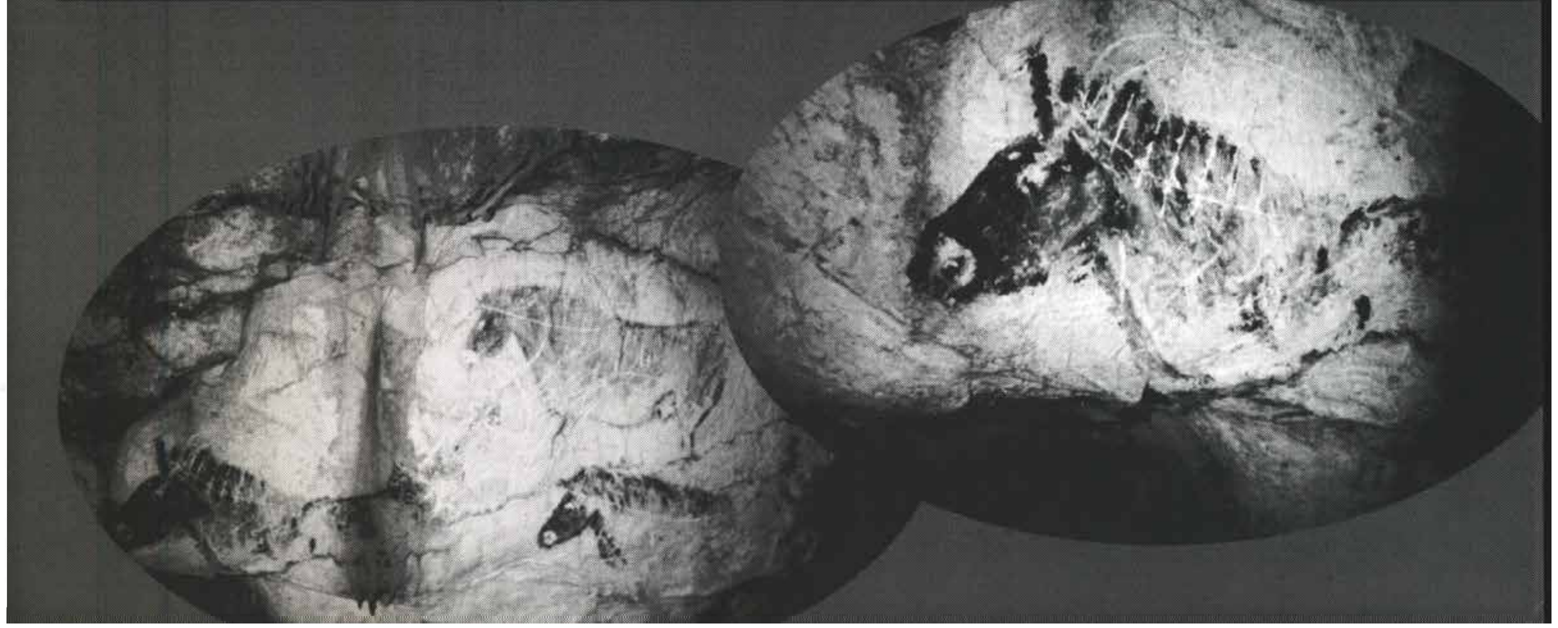


discovered French cave paintings estimated to be 15-18,000 years old, photographed by a team of cave divers during a "nonofficial" visit to Grotte Des Grenoblois • Marseille, France. The site has been declared a French national treasure, and is off limits to divers.



Straightening Out the Bends

Ongoing Research on the Social Reaction and Stigma Surrounding Decompression Illness

Illustrations by: Gennady "Jack" Zhivutsky

by Jennifer C. Hunt

The experience of decompression illness is traumatic to the victim as a result of the physical nature of the injury and its link to deeper psychological issues. The strong negative social reaction and stigma surrounding DCI increases the trauma, and jeopardizes the healing process. In order to protect against the resulting feelings of anxiety, shame, humiliation, guilt, and incompetence, the diver may mobilize defenses and engage in behaviors that temporarily ease the psychological burden but ultimately have negative consequences for the individual, as well as the diving community as a whole.

The DCI experience

Decompression illness is potentially traumatic. The "hit," the chamber treatment and the rehabilitation period are all physically and psychologically painful. Analysis of DCI as a psychological phenomenon is complicated by the possible organic effects that the illness may have on the diver's mental functioning, particularly during the initial hit.

In severe cases, the onset and immediate aftermath of DCI are acutely painful. As in major surgery and long-term illness, rehabilitation can be excruciatingly slow. During the onset of DCI, thinking processes may be disturbed, and the diver automatically uses protective devices to keep from experiencing the terrifying anxiety that could occur with the realization that he or she could die.

For example, this diver knew that he would be bent when he made the decision to ascend but excluded conscious recognition of the possibility of permanent injury or death.

"I never let it enter my mind that I would be permanently crippled or dead. My thoughts were, 'I have to get to the surface. I am in danger underwater. I can't function anymore,'" he said. "I remember being in the boat. It was hard breathing. I knew I had really put my body through the ringer. I closed my eyes and everything went black. I saw stars and heard the chimes [over my child's] crib. My family needs me. The pain was so intense."

If the victim survives the accident with minimal physical damage and is able to dive again, community reaction to the accident remains a concern. Divers fear that their identities will be spoiled and past accomplishments reinterpreted negatively.

The immediate concern for the diver with DCI is the threat of death. Like the young athlete who sustains severe injury and must face the reality that he or she is not invincible, bend victims may suddenly become aware of their physical vulnerability and lack of control over their bodies.

One diver recalled the book *"Titanic: the End of a Dream"* while discussing his accident. He explained, "The *Titanic* represented the age of science. We were supposed to conquer everything with our knowledge of science, and it was deemed virtually unsinkable. When it sank, people were shocked. We can't control things." The *Titanic* represented this diver's fantasy that he could not be hurt. Its sinking symbolized his own vulnerability.

If the diver survives, the threat of other physical losses becomes paramount. These include the loss of bodily functions that have previously been taken for granted (urination, sexual response, walking, running etc.). Concerns about bodily damage are associated to fears of losing important professional and leisure activities and key relationships. One diver expressed the fear that she would be disabled and lose her job. Another was concerned that her fiance would abandon her.

If the victim survives the accident with minimal physical damage and is able to dive again, community reaction to the accident remains a concern. Divers fear that their identities will be spoiled and past accomplishments reinterpreted negatively. One diver commented, "All my work for naught. I guess I am worried that I won't be taken seriously. Will my [diving] career be ruined?"

Diving is not only a social activity but also a deeply private one. A fundamental concern of any serious diver who "takes a hit" is the loss of diving itself, a deeply meaningful experience which lies at the core of the person's being and defines him or her as fully alive. Here arises a fundamental contradiction of the sport. The very activity that allows some individuals to feel fully alive may also bring them closer to death. While sport divers all negotiate this contradiction, it is experienced most dramatically among the technical community, deep divers, cave divers, and wreck divers, as the following two accounts reveal. "Emotionally I was devastated. It was like being told a part of me was going to die. We have never lived more than a mile from the water. Water is a part of my life and I was losing that,"said one diver.

Said a victim who sustained serious damage and has been unable to dive since the accident, "I am a water person. I just love water and the beauty of the textures, colors, light all around me. I do miss it very much."

Every accident has internal echoes. The current meanings of DCI can become linked to a set of past experiences which may not be within the diver's conscious awareness. This mobilization of past memories in the face of a traumatic event is routine and not necessarily "pathological." Only if the internal echoes haunt the diver to such a degree that he or she experiences inappropriate guilt, shame, sadness and rage or the echoes interfere with his or her resolution of the trauma in a way that precludes pleasure in work and play, can we assume unresolved conflict and so-called "pathology."

Typically divers associate DCI to past injuries, accidents or illnesses in which they also felt helpless, damaged and frightened. The events leading up to the DCI experience can also link to significant relationships from the past. One women whose father was an alcoholic became bent while diving with a male buddy with whom she had an erotic attachment. She went along passively with his wishes. Although she was afraid of sharks and not particularly interested in deep diving, she followed him to 172 feet to photograph sharks. She trusted him, omitting consideration of a three-day pattern of diving that embroiled her in one deeper dive after another. Her dependence on and obedience to an essentially untrustworthy buddy appeared to be, in part, a repetition of her early relationship with her father. Like most children who are physically or emotionally abused, she turned to the abuser for love and protection, only to find herself hurt again.

"If you...can't move your arm and leg, it's obvious to everybody that you are bent. But if you just have some mild neurological symptoms, no one wants to hear about it."

Another diver grew up in a family in which one parent was seriously ill. The diver saw her own childhood illnesses as insignificant compared to those of her father, who could suddenly die. Her father was distant and detached. In contrast, her mother was smothering. The mother was also a hypochondriac, who used her ailments to keep her daughter close. If the daughter was involved in some joyous activity, the mother would often become ill and spoil the occasion.

When the diver experienced DCI symptoms, she tried to ignore them despite mild, partial paralysis. She explained, "If you...can't move your arm and leg, it's obvious to everybody that you are bent. But if you just have some mild neurological symptoms, no one wants to hear about it."

The diver experienced her hit in a manner similar to childhood illness. Unless she were near death like her father, she could not take herself seriously and had to deny the importance of her symptoms. Recognition of mild DCI symptoms brought to mind her mother's smothering attitude. It also reminded her of how the mother would manipulate her ailments to spoil good times. If the diver were to admit her illness to herself and others, she unconsciously feared that she would be like her mother, a hypochondriac and spoiler. Denial not only protected the diver against anxieties associated with DCI but also against an ambivalent identification with and entrapment by her mother.

In view of the multiple meanings of the decompression trauma, the diver mobilizes defenses against experiencing internal and external danger, unbearable anxiety, intolerable thoughts, memories and fantasies. In general, such protective devices constitute normal mechanisms of the mind and are constituted unconsciously and automatically. Under certain circumstances, such as some major traumas, the defenses mobilized may help the individual survive the immediate threat but at a considerable cost to future functioning.

The diving community is familiar with the term *denial*, coined "the first symptom of DCI." Unfortunately, however, diving literature reveals some confusion about the nature of the defense mechanism. Defenses are sometimes presented as unhealthy, intentional and/or irrational means to sabotage good medical treatment rather than occasionally costly efforts to manage psychological stress. One writer, for example, referred to one victim's near delusional denial of severe symptoms of DCI as "ludicrous." (Viders, 1991).

Denial is not the only defense divers use. Joking and excessive concern with a buddy provide other means of protection. Divers also try to minimize the guilt and shame associated with making mistakes by shifting the blame to something outside themselves. They may engage in attacks on the self in order to keep a lid on the rage they feel towards others. Admission of their own participation in an accident is particularly painful for some divers, because they recognize that there is a part of themselves they do not control which encourages them to take risks and suffer injury.

Social reaction

Dive communities tend to categorize victims as "good" or "bad." The definition of the "good" and "bad" victim varies depending on the diver's community of affiliation. In general, "bad victims" include divers who exceed the limits of accepted no-decompression or decompression dive tables, whose dive profiles are deemed irresponsible, who run out of air or otherwise make mistakes viewed as unacceptable for a good diver. The "good victim," in contrast, includes the uneducated or inexperienced diver who couldn't possibly know his or her profile or dive related behavior was risky. For example, one diver was bent as a result of engaging in rigorous exercise after diving. He was not held morally responsible for the accident because he had been unaware of the dangers of post and pre-dive exercise. The "good" victim also includes the diver whose profile was within the limits of the relevant dive tables or who made an error deemed socially reasonable, such as the diver who is bent in the process of a rescuing a student or buddy. The definition of a "reasonable" and "unreasonable" mistake changes with the dive community

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"Good victims" are not viewed as morally responsible for their illness and do not experience strong negative social reactions. "Bad victims," in contrast, are viewed as culpable and deserving punishment.

A recent article on computer dive accidents highlights this distinction. "Bends appear to fall into two distinct categories: 1) undeserved hits (mystery accidents), and 2) deserved hits (resulting from violations of safety procedures)." (Murphy, 1992). Categorization of the "bad" victim is subject to flux, depending on whether the diver admits a mistake and how he or she publicly handles the accident.

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The diver with DCI can be compared to a woman who has been raped. In the minds of some communities, there is only one real rape victim, a young woman of limited sexual experience or a married woman who does not drink, take drugs, engage in extramarital sex, wear revealing clothes or take unnecessary risks like walking alone at night in environments deemed dangerous. Other victims of sexual abuse are often seen as morally responsible for their attacks and deserving of punishment as a result of their seeming flirtation with danger. One male diver compared the DCI experience to a rape scene in the film *Cape Fear*. The brutal jokes made by police officers about the victim were compared to colleagues' reactions to a bends victim.

Many "good" victims receive support from family, friends, and medical personnel. Among "bad victims", however, there are numerous instances in which the reactions of significant people and organizations are negative. This includes stigmatization by important people and/or organizations including dive shops, medical personnel, dive operators, colleagues and buddies. The negative social reaction and stigmatization of "bad victims" has a number of consequences for the diver's identity and behavior as well as for the dive community as a whole.

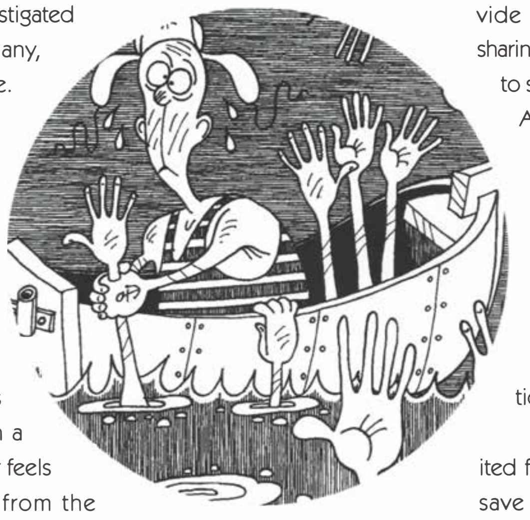
In some respects, divers affiliated with cave and possibly technical communities may be less stigmatized than some recreational divers, as long as their practices obey informal rules governing skilled, decompression sport diving. One diver explained, "[If you are a cave diver], you know you can take a hit. A lot of people have lost friends, know people who have died or have been associated with a body recovery. Reef divers and wreck divers don't have the same sense of community as cave divers." On the other hand, negative sanctions against divers who make "unreasonable" mistakes may be particularly severe in the cave diving community. This is because the cave diver who makes a mistake is likely to die.

Most divers are linked to more than one diving community and may experience different reactions from each. As a result, the injured technical or cave diver cannot always insulate him or herself from stigmatization, regardless of how the accident is viewed within "advanced" communities. Instructors, and would be instructors may be particularly vulnerable as a result of multiple affiliations.

Dive shops: Dive shops involved in training and education may take a particularly hard line when they discover that employees are bent. This is partially economic. Many shops depend on training agencies for their ratings, which they fear will be compromised if too many instructors get DCI. The shop's public image is also at stake, and managers fear losing customers. Managers assume that potential divers will be discouraged from diving if they are fully aware of the risks involved. Alternatively, students may interpret bend cases among the instructional staff as an indication of institutional weakness and seek training elsewhere. Finally, managers are concerned with their students' welfare. They reason that students "do what instructors do

and not what they say." If students learn that admired instructors dive below 130 feet, make mistakes or get bent, students may exceed the limits of their skills in the false belief it will make them "real divers."

As a result of these and other factors, managers tend to react punitively when instructors are bent, treating their accidents as a criminal, rather than a medical or psychological, matter. Managers may make quick decisions regarding punishment before the accident has been fully investigated to determine what, if any, sanctions are advisable. Instructors' classes are likely to be canceled and future teaching opportunities denied until the diver is able to earn his or her way back to respectable status. Past accomplishments are sometimes seen in a new light, and the diver feels he or she must start from the beginning to prove him or herself.



Instructors who have DCI are not only often treated like criminals but also like children who must be punished for doing something bad. One diver explained, "We got reprimanded for getting bent in the first place. As if we hadn't beaten ourselves enough, they are going to beat us up too."

The diver resents being treated like a criminal and a child and becomes increasingly alienated from management. Like the adolescent who is still dependent on his or her parents but is unwilling to submit totally to their restrictions, the instructor learns that lying about accidents is better than admitting mistakes. Instructors invent "cover stories" to avoid confrontations. This not only increases the distance between management and staff but may also compromise the instructor's medical treatment. If he or she is bent in the future, treatment may be avoided or delayed in order to reduce the risk of discovery that could result in punishment.

Nevertheless, "bad victims" are sometimes targets of tactless comments by frustrated physicians who view "high-risk" diving as a challenge to their ability to rescue and heal.

When the DCI victim does resume teaching, managers may discourage discussion of the accident or other mistake with students, although some instructors informally violate this rule. One diver explained, "I got a lot of grief about it because I did something stupid and admitted it publicly. But two guys died in similar circumstances. I wanted to save someone's life. [A manager] said it made me look like an idiot. I guess they're afraid it will hurt their wallet. I just thought if you teach your people better about getting hurt, then they are less likely to get hurt."

Instructors who have DCI are not only often treated like criminals but also like children who must be punished for doing something bad.

The prohibition against sharing the DCI experience may be particularly problematic, because it interferes with the individual's effort to heal psychological and physical damage. Sharing of the DCI experience can be reparative. By using his or her accident as an educational tool, the instructor attempts an early rescue of students, offering them the protection that he or she was not able to provide him or herself. Educational sharing of the DCI trauma is helpful to students as well as instructors. A diver explains, "I thought it would help someone, keep them from doing what I did. I felt good about talking. I didn't know for sure that I would until I got up there. I think it did help, because people asked a lot of questions."

DCI victims who are prohibited from using their experience to save others may ultimately have more difficulty healing themselves. This is the case for one diver who was denied the opportunity to tell novice divers about her accident.

"All I ever have gotten back from them is criticism, that it was my fault. The holier-than-thou attitude which still angers me," she says. "Also I have offered to talk to novices about my situation and no one has ever asked me about it. If I could teach someone, have them learn from my experience, maybe I would get some good feelings about what happened. I would hate it if someone else got into the circumstance I did. I would like to serve as a personal example, so that people might take better care of themselves."

Medical and hyperbaric specialists: Some medical and hyperbaric organizations have taken a public stance advocating diving safety and discouraging practices they believe put divers at risk. It is certainly consistent with the goals of medicine to discourage activities that may lead to illness or injury. However, the politicalization of dive medicine and the moral stigma attached to decompression illness are not without costs to patient care and scientific research.

The public attitudes of admired representatives of the medical community structure opinion and behavior among a variety of persons engaged in the care of injured divers. Informal attitudes may be directly transmitted to hyperbaric personnel who work with and talk to respected physicians. This was the case during a professional conference for physicians and hyperbaric specialists. An X-ray was shown of a diver with air between his skull and brain. The presenting physician described the diver's seemingly irrational, high risk profile and proceeded to call the patient an "airhead." This physician's remarks inadvertently sanctioned ridicule of patients categorized as "bad victims" to an audience involved in patient care.

Divers suffering from DCI who seek advice and treatment from hyperbaric specialists are generally provided competent and professional help. Nevertheless, "bad victims" are sometimes targets of tactless comments by frustrated physicians who view "high-risk" diving as a challenge to their ability to rescue and heal. Stigmatizing reactions on the part of physicians are particularly potent in view of the inequality of the doctor-patient relationship and the patient's vulnerability.

Patients are also in a position of physical and psychological vulnerability. First, they are sick and needy and do not have the ability to treat themselves. Second, they are willing to provide the physician knowledge about private and potentially embarrassing aspects of also their Uves in the interests of their with care. The "bad DCI victim" may be especially vulnerable to abuse of the doctor-patient relationship, because he or she is already engaged in a critical self-assessment and may have experienced negative reactions from dive colleagues. Five out of six "bad victims" that were interviewed related interactions with medical professionals that they experienced as hurtful and even degrading.

Typically, "bad victims" call a dive medicine organization for advice regarding DCI symptoms and encounter unprofessional remarks about their diving practices. One diver revealed her profile and was told in what she perceived as a critical tone, "That's way off the tables." A hospitalized diver with a severe case of DCI was repeatedly questioned by nurses and doctors regarding the depth of her dives, despite their irrelevance to ongoing treatment. Although medical personnel may just have been curious, the diver experienced these inquiries as intrusive accusations by incredulous listeners. In a confidential exchange between two doctors about a DCI patient, the referring doctor included in his letter a number of remarks that had nothing to do with diagnosis and treatment, reflecting instead his negative attitude about the patient and her "irresponsible," "dangerous" and "irrational" dive pattern. Upon discovering the letter, the patient was mortified.

Technical divers often avoid interactions with representatives of dive medicine organizations because they anticipate a negative response in view of the political positions such organizations take about deep diving. One diver explained, "Most of us don't call [the medical organization] because when you tell them your profile, you know what they're thinking: 'You asshole'" In contrast to some recreational divers who do not have strong community affiliations, the technical diver is at an advantage. He or she has access to names of physicians who specialize in dive medicine and are less likely to infuse the examination with moral judgements. These physicians can consult with members of medical organizations regarding the divers health without putting the diver at risk of experiencing moral sanctions.

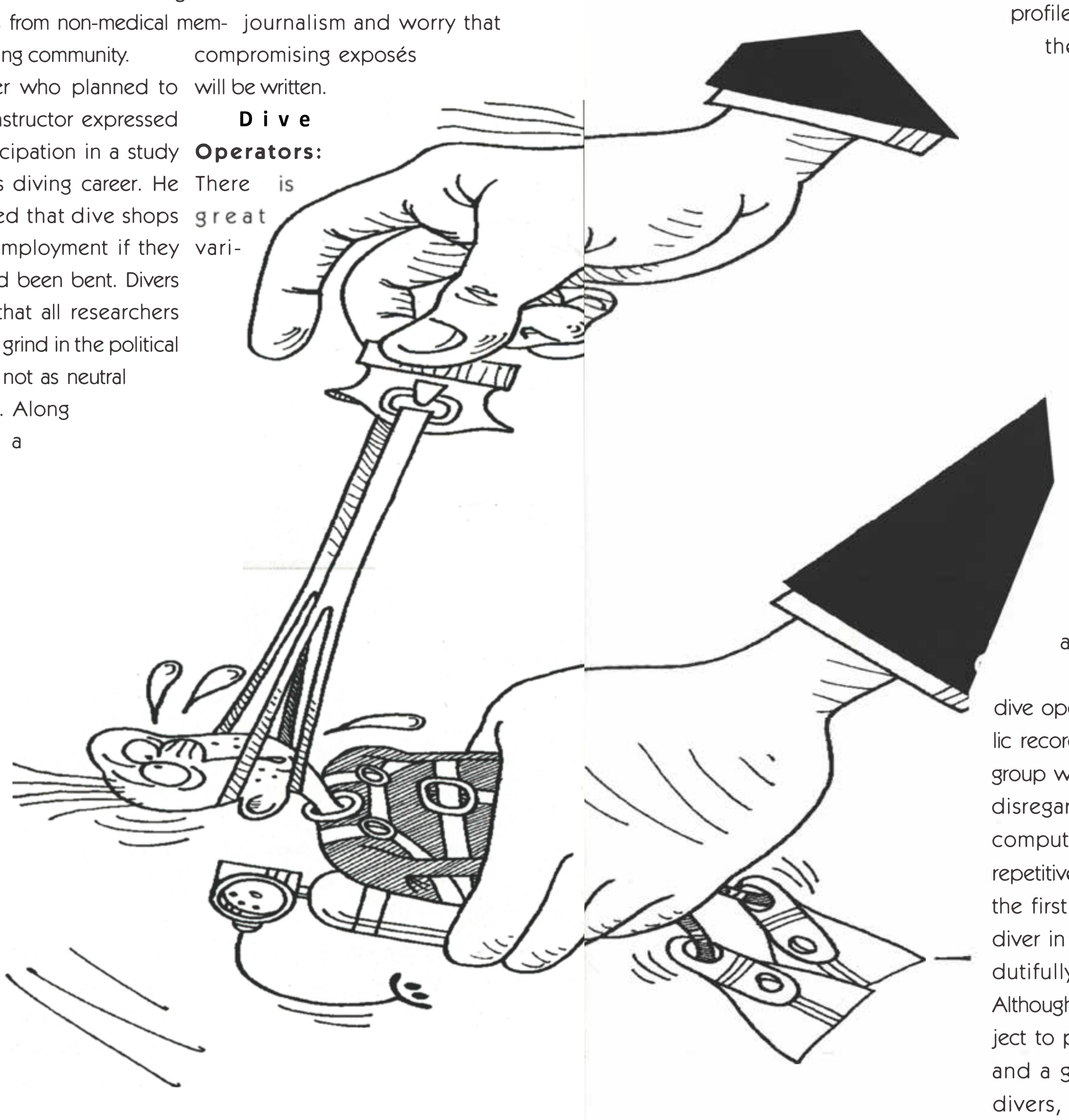
A number of problems result from the occasional tension between divers and doctors. Patient care may be compromised, because divers with mild DCI symptoms hesitate to consult with doctors who they fear will judge their diving practices and make them feel ashamed. Or divers may lie to doctors about their profiles or drug/alcohol consumption in order to protect themselves from moral judgements. They may omit some of the information needed for appropriate diagnosis and treatment.

The politicalization of diving and the moral stigma attached to decompression illness has compromised the ability of medical and other researchers to pursue objective research. Some "bad victims" refuse to fill out forms used for statistical and other purposes because of their discomfort with the attitudes of the medical organization sponsoring the studies. Divers also fear that researchers will compromise claims of confidentiality and reveal their accidents, subjecting them to further negative sanctions from non-medical members of the diving community.

One diver who planned to become an instructor expressed fear that participation in a study could ruin his diving career. He was concerned that dive shops might deny employment if they learned he had been bent. Divers also assume that all researchers have an axe to grind in the political arena and are not as neutral as they claim. Along these lines, a diver decided not to share her experience of decompression illness apparently because she did not believe the researcher's claim of neutrality and was concerned about her supposed allegiances.

Finally, dive shops and others may themselves discourage certain kinds of research. In one case a dive shop told its instructors to avoid participation in a study by an established scholar. Further data is needed to determine precisely why training managers are threatened by research. Many are unfamiliar with certain kinds of research and assume it could have negative effects on business. They may associate some research journalism and worry that compromising exposés will be written.

As a result of these and other factors, managers tend to react punitively when instructors are bent, treating their accidents as a criminal, rather than a medical or psychological, matter.



Dive Operators: There is great variation in policy and practices regarding diver safety. Warmwater dive operators in particular are more likely to serve a variety of unknown divers of varied skill and experience. Liveaboards tend to attract a class of divers who want to avoid the limitations of shore operations and maximize their underwater freedom. Many liveaboard operators are particularly concerned about diving safety because of the risks involved in repetitive diving among an unknown population of divers.

Nevertheless, warmwater operators vary in how they view their responsibility and the precautions they are willing to take.

A number of operations appear to provide mixed messages to divers. For example, they may formally proclaim concern and informally practice neutrality. On one hand, dive briefings may limit dive depths and times. Captains and divemasters may require formal recording of dive profiles. Divemasters will make themselves available as guides and offer help if problems arise. Informally, however, there may be a "dive your heart out but don't ruin the trip" attitude on the part of dive leaders. As a result, divers may have a false sense of security and/or be confused about what they really should do if a serious problem should arise.

In one case, a liveaboard dive operator requested the public recording of dive profiles. One group was making daily dives that disregarded known rules about computer use, depth, time and repetitive diving limitations. During the first three days, at least one diver in the "deep diving" group dutifully recorded her profiles. Although the dives were likely subject to private comment by crew and a group of "conservative" divers, no one took any of the deep divers aside to discuss their profiles. On the third day, the woman made a third dive below 165 feet. When her computer indicated that she had no more time at depth, she abandoned her buddy and began her ascent. She lost consciousness at 10 feet and sustained a serious hit.

She later explained, "I felt angry. I was angry at my own stupidity. Why hadn't I paid attention to the fact that I was diving deeper? I looked at my profile and I was angry at the captain and I was angry at the divemaster. Had the divemaster said to me, 'Do you realize what your profile looks like?' I would have listened. I would have heard it as a criticism, but I would have listened. The cook told me later that the divemaster said that she thought we were all professionals. She didn't have the right to say anything to us because we were all professionals."

In pre-dive announcements, divemasters commonly express concern about safety and make clear that injured divers should report problems to crew. In the same briefings, divers are warned that if they get DCI, it will ruin everyone else's trip, because the boat will have to go ashore.

Hearing these mixed messages, divers are likely to hesitate to confess their fears of illness lest they antagonize crew, buddies and friends. Social support is also provided for divers' desires to deny injury. One diver explained, "If this had happened to me in the middle of the trip, I would not have considered telling anyone for a second. They would have had to turn the boat around and go back. They tell you that you better be careful, because if you have to turn around and go back, it will spoil everybody's trip. You know that people just put down a thousand dollars for this trip and if they have to turn around and go back because of you, you aren't going to be a real popular person."

After the last dive of the trip, this same diver experienced symptoms of DCI and did not discuss them with the divemaster because she feared his reaction. She continued to conceal her fear that she had DCI when they arrived on shore, despite some mild symptoms of paralysis.

Dive colleagues and buddies: Dive buddies may also inadvertently collude with the injured diver's desire to deny or minimize the seriousness of the injuries. One diver finally told her buddy about her concerns, and the buddy overtly displayed displeasure. As a result, the diver decided she would not further annoy her partner by telling him she wanted to go to the hospital. When the symptoms worsened on the plane ride home, the diver again mentioned her concern and discussed her desire for oxygen. The buddy remained firm in his insistence that the problem was not serious, claiming, "They will never give it to you because they need it for real emergencies." The diver did not ask for oxygen and delayed treatment until she returned home. The chamber brought little relief, and she suffered fatigue for many months. Mild DCI symptoms remain, perhaps as a result of delayed treatment.

A male diver was bent while attempting to rescue his inexperienced wife and buddy. He decided to go to the chamber when ini-

"[If you are a cave diver], you know you can take a hit. A lot of people have lost friends, know people who have died or have been associated with a body recovery. Reef divers and wreck divers don't have the same sense of community as cave divers."

tial symptoms of nausea and vertigo persisted into the night. Prior to his decision to seek treatment, the diver expressed his fear that he was bent to his buddy, who denied the possibility and insisted that food was the culprit. Even after a chamber ride brought some relief, she insisted that, "If you had just slept it off instead of going to the chamber in the middle of the night, you'd be fine."

Joking and sarcastic remarks constitute another way that buddies often react to accidents. Some jokes are friendly; others are ambivalent or overtly hostile. Regardless of intent, jokes are not always welcomed by the DCI victim, who may experience them as attempts to cause pain and humiliation and/or minimize the seriousness of his or her illness.

Typical among divers are "bend presents" commemorating the accident. One diver who got DCI after making a 200-foot dive received a coffee mug stating "Divers Do It Deeper." Other victims typically receive T-shirts, some of which are illustrated with personal messages and cartoons. One diver graciously received his present in the hospital. Although he pretended to be pleased, his feelings were mixed. He explained, "At first I didn't like it. I felt like I was being discredited. I had a good reputation. Now I felt it was spoiled. After a while I realized that it was their way of handling it. It had as much to do with them as with me."

In contrast to jokes, which can be tolerated by most victims, tactless and sarcastic remarks are experienced as degradation ceremonies intended to shame and humiliate the injured diver. One diver was referred to as "Mr. Fizz" at a public forum. A colleague introduced a DCI victim to the colleague's girlfriend at a party. After discovering that "this is the guy who got bent," she remarked to the victim, "stupid, stupid, stupid." A "friend" of one victim, herself just beginning to engage in decompression diving and apparently quite fearful, commented "So is fatigue still your excuse [for getting bent]?"

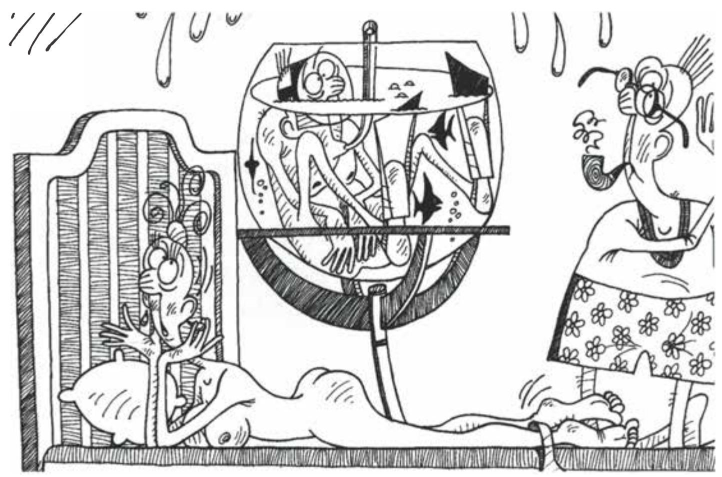
DCI victims handle such remarks differently, depending on their personality and the nature of outside support groups. However, few divers are able to isolate themselves from their feelings sufficiently to avoid feeling angered and humiliated regardless of how they publicly deal with stigmatization. One diver commented, "I felt like smacking him. I take the comments very personally. You read between the lines. 'You are a bad diver.' That is how I take it when people make these kinds of comments, and I don't like it. Some of these people will never shine a torch in the places I have been."

One diver was able to protect himself against the verbal assaults by trying to understand the aggressor's motivations. Nevertheless, he still experienced the remarks as insulting and degrading. He explained, "You feel very vulnerable, and people exploit that vulnerability... because of their own fears. I was at a party and Jay comes up to me and starts making these jokes. 'So Dan, where ya gonna be diving this year?'" Jay listed a series of novice dive sites. "Like this is so beneath a diver to be diving these things," the diver continued. "His attitude is that he wants to go deeper, longer, further than other people, to prove he is better, to out-macho everybody. Good way to get himself hurt."

As negative social reactions become more evident, divers may begin to read between the lines of any social interaction. They know that people are talking about them, because they hear about some of the conversations. Some discussion that goes on behind the diver's back is well intended. However, the diver does not know the context of conversations and cannot know who is thinking what. Reality and fantasy are confused, and the more vulnerable divers are likely to find it difficult to face the world, anticipating and feeling shame wherever they go.

With time, a number of victims are able to resolve the trauma of DCI and subsequent social assault with relatively few disabling psychological scars. Others are not.

One woman, stigmatized as a "bad victim" and subjected to a severe social reaction, still lives in torment several years after her accident. She continues to vacillate between blaming herself and blaming others. Sometimes she attributes her accident and/or physical disabilities to her computer, an irresponsible dive operation and a catheter. At others, she becomes involved in endless attacks on herself. Her defensive fluctuations, which alternately protect her from shame and humiliation or intolerable rage, provide no relief. This diver cannot forgive herself for what happened and has little understanding of why she put herself at risk of injury. She often feels as though she was punished and sometimes she thinks she deserved it.



Indeed, the diver feels like a rape victim in a trial in which she becomes the criminal in the eyes of attorneys, judge, jury and even herself."I did talk to an attorney and I considered a lawsuit against the computer manufacturer," she says, "but the laws are based on what you do, and I didn't make my safety stops and was diving an irregular pattern. So it wouldn't matter if the manufacturer hadn't repaired the computer when I sent it in. It probably would have been thrown out of court. And also all the embarrassment of being dragged through all of this and being told that I was wrong. Rape. Yes it does feel like a rape. If you were to do it over again, you would do something different, in my case with depth and profile. But at the same time no one will even pat you on the back and say you must feel very bad. Instead, they all start asking questions and pointing fingers immediately, and all the fingers unfortunately tend to be pointed at me. I feel like I have been punished. Yes I deserved it. As I am speaking, I can realize that it's ludicrous ,but I hear myself saying it as well."

"Most of us don't call [the medical organization] because when you tell them your profile, you know what they're thinking: 'You asshole'"

Editors Note:
The following ~~intra-corporate~~ memo arrived by mojo wire from Colorado shortly before the deadline time for this issue.

Gonzo Diver Bent

"The circumstances of Dr. (Hunter S.) Thompson's removal from the Public World have been a carefully guarded secret for the past several months. During the last week of March—after a strange encounter with Henry Kissinger while on "vacation" in Acapulco—Dr. Thompson almost drowned when his SCUBA tanks unexplainably ran out of air while diving for black coral off the Yucatan Coast of Mexico, at a depth of some 300 feet. His rapid emergence from these depths—according to witnesses— resulted in a near-fatal case of the Bends, and an emergency-chartered/night-flight to the nearest decompression[sic] chamber, which happened to be in Miami."

"Dr. Thompson was unconscious in the decompression chamber—a round steel cell about 12 feet in diameter—for almost three weeks. *'I'll never understand why he didn't wither up and die."* reported Dr. Squane, Miami's Bend Specialist, *"Only a monster could survive that kind of trauma."'*

"Memo from the Sports Desk & Rude Notes from a Decompression Chamber In Miami," Hunter S. Thompson, *Rolling Stone*, #140, 2AUG1973.

Special thanks to Rolling Stone Magazine for allowing us to reprint Dr. Hunter S. Thompson's story and congratulations on their 25th Anniversary.

Getting Straight On The Bends

Resolution of an illness involves coming to terms with feelings of bodily damage and fears of loss. It also involves a largely unconscious process of managing the complex web of images from the past which mediate the illness and its aftermath. In the face of social assault, divers are encouraged to maintain defenses such as externalization, denial and self-recrimination, which may minimize some immediate danger but can compromise their long-term psychological welfare.

Without this external assault, divers are far more likely to allow themselves to experience gradually the full range of feelings and thoughts that accompany DCI. In the process, "compromising" defenses can be substituted for others that are less costly to future functioning.

Some divers, feeling socially discredited and depressed after a prolonged illness, may go back to diving before they fully understand the dynamics of their accidents and have resolved the trauma. In their minds, only diving can restore self esteem by proving to themselves and others that they are socially worthy members of the diving community. Some divers may also grow increasingly committed to high-risk diving subcultures, which are sometimes more willing to view DCI as an occupational hazard and accept the injured diver as one of their own.

Not only does the stigmatization of DCI increase psychological stress, it also has a deleterious effect on medical treatment. Fearing moral sanctions, divers are likely to delay seeking medical help and/or omit information about the accident which could be important for diagnosis and treatment. This can result in the diver sustaining permanent physical damage, as recompression treatments are only effective when they are instituted soon after the onset of illness.

Finally, the stigmatization of the DCI victim has negative effects on the diving community as well as on individual divers. It results in the alienation of certain groups of divers from dive shops and increases organizational conflicts. It also compromises the ability of researchers to pursue quality diving studies that could benefit the diving community.

DCI is not a moral disease and should not be treated as one. To do so damages the victim's chance at full physical and psychological recovery and has a negative impact on the diving community. This recognition does not constitute an acceptance of practices that some segments of the dive community feel put divers at risk. It simply acknowledges that divers who are bent suffer a serious physical illness that can have far-reaching psychological consequences. Victims of decompression illness deserve understanding and treatment rather than social ridicule.

Jennifer C. Hunt, Ph.D., is a sociologist and a Clinical Instructor of Psychiatry at the New York University Medical Center, who is currently concluding a study of the social and psychological dimensions of DCI. She can be contacted at: 438 E 58 St., New York, NY 10022.

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Acknowledgements: I am deeply indebted to the divers who have shared their experiences with me. They know who they are. I would like to thank Michael Menduno, Mike Emmerman, and Stephen K. Firestein M.D. for their ongoing encouragement. I am especially grateful to Bernie Chowdhury for his comments on parts of this manuscript and his continued support of my work.

More information...

Arcott, Chris. 1991. "Does Diving Drive You Crazy? Psychotic Aspects of DCS." revised transcript of 1990 lecture. Undercurrent 17:11-12.

Dan, 1992. 1990 Report on Diving Accidents and Fatalities. Divers Alert Network. Durham, N.C. 1992.

Goffman, 1963. Stigma: Notes on the Management of Spoiled Identity. Englewood Cliffs, N.J: Prenctice Hall.

Katz, Jay. 1984. The Silent World of Doctor and Patient. New York: The Free Press.

Kleinman, Arthur. 1988. The Illness Narratives. New York: Basic Books.

Konner, Melvin. 1988. Becoming a Doctor. New York: Penguin.

Murphy, Geri. 1992. "Responsible Computer Diving." Skin Diver: 69-70. April.

Shapiro, Martin. Getting Doctored: Critical Reflections on Becoming a Physician. Philadelphia: New Society Publishers.

Viders, Hillary. 1991. "It Can't Happen to Me." New York SubAqua Journal Vol. 1#6:4. September.

technology

Tiny Bubbles:
A Primer On Doppler Bubble Detection

By R.Y. Nishi

A considerable amount of interest recently has arisen in Doppler ultrasonic bubble detection and its application to decompression research and diving operations. As a result, some misunderstandings exist about the role of bubbles that the Doppler instruments can detect and the relationship between Doppler-detected bubbles and decompression illness (DCI). Although many mechanisms may be associated with DCI, the most probable initiating factor is still believed to be the formation of bubbles. Early decompression studies suggested the presence of "silent bubbles" that did not result in DCI signs and symptoms, and considerable research was conducted in detecting bubbles with ultrasound. The Doppler ultrasonic bubble detector is the simplest, most convenient and most practical method for observing bubbles in humans. However, it can only detect intravascular bubbles, i.e., bubbles moving through the circulatory system, and it requires skilled personnel to use and interpret the bubble signals.

A History of Doppler

Decompression researchers have used Doppler ultrasonic bubble detection as a tool for almost 25 years. Its origins go back to 1968 when two groups of researchers, Spencer and Campbell (working with sheep) and Gillis, Peterson and Karagianes (working with pigs) reported detecting decompression-generated bubbles with Doppler flowmeters. In 1968 Spencer reported the first detection of bubbles in humans. In 1970, the Spencer Precordial Bubble Detector was developed expressly for detecting decompression-generated bubbles (available from the Institute of Applied Physiology and Medicine (IAPM), Seattle, Wash.). This instrument was designed to monitor blood-flow in the heart's right ventricle or in the pulmonary artery. Spencer and Johanson devised a grading and coding scheme for classifying bubbles, based on a scale from 0 to 4.

Due to its potential for decompression studies, a number of researchers soon adopted the Doppler technique. For example, Pilmanis found that "no-decompression dives" could produce high levels of bubbles and that a short safety stop was effective in reducing bubbles. In Japan, the Doppler ultrasonic bubble detector was used extensively for monitoring compressed air workers as well as divers. Spencer conducted an extensive study on no-decompression (no stop) dives with divers in both hyperbaric chamber and in the open ocean. This work was later used by Huggins to develop the Michigan Sea Grant no-decompression repetitive dive tables and the algorithm for the EDGE dive computer. Although Huggins' No-D table has become commonly known as the "No-Bubble Tables," Huggins actually used Spencer's limits for bubble formation.

In France, Guillerm and Masurel of the French Navy carried out considerable work on Doppler bubble detection. Together with the Institut National des Sciences Appliquees in Lyon, they developed better instrumentation and transducers for bubble detection. (The precordial bubble detector that was developed was later marketed by Sodelec S.A. of Marseilles.) In 1978, Kisman from Canada's Defense and Civil Institute of Environmental Medicine (DCIEM), who was developing a computer program to detect and grade bubbles, went to France to work with Masurel. Together, Kisman and Masurel developed a more comprehensive bubble grading scheme that was believed to be much easier to learn than the Spencer Code and that could also be adapted easily for use for computer grading of bubbles.

In recent years, there has been a resurgence in the use of the Doppler bubble detectors for monitoring divers and evaluating dive profiles, particularly in the recreational and scientific diving communities.

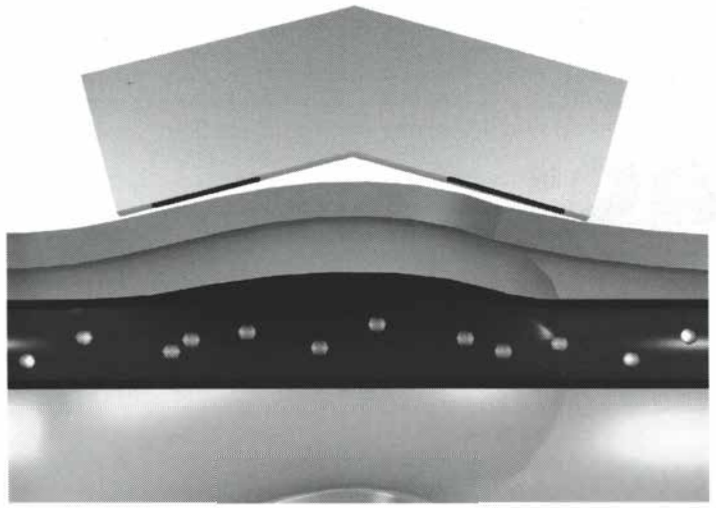


Illustration by: Michael Bielinski

Research at DCIEM included both theoretical and experimental studies into bubble detection and the scattering and absorption of ultrasonic waves by bubbles. Considerable work was done in developing a computerized method for detecting and grading bubbles. In 1979 DCIEM embarked on an extensive program using the Doppler method to assess decompression models, profiles and diving techniques. This work led to the development and validation of the DCIEM air diving tables and the just-completed helium/oxygen diving tables. Because of a need for a highly reliable and readily available Doppler instrument, DCIEM was also involved in the development of a precordial Doppler ultrasonic bubble detector (manufactured by Techno Scientific Inc., Woodbridge, Ont.).

In recent years, there has been a resurgence in the use of the Doppler bubble detectors for monitoring divers and evaluating dive profiles, particularly in the recreational and scientific diving communities. For example, studies conducted by DAN have shown that typical sport diver profiles can result in detectable bubbles. Doppler was also used in testing the new DSAT/PADI dive tables for multi-dive, multi-day diving. Recent work by Eckenhoff and colleagues on shallow air saturation dives has been directed at obtaining a better understanding of the fundamental mechanisms of bubble formation and decompression in humans. Doppler bubble detection has also been used at altitude for aircrew and in space.

Measurement Techniques

The most common location for monitoring bubbles in humans is the chest (precordium), either the pulmonary artery or the right ventricle of the heart. Ultrasonic waves are transmitted into the blood flowing in these locations, and any bubbles present in the flow can be detected as echoes among the background noise produced by the red blood cells and other particles in the blood. Theoretically, since the entire venous system drains into the right ventricle, any decompression-generated bubbles should be detected at this location. In practice, however, not all bubbles can be detected. For example, sometimes bubbles can be detected in the subclavian veins in the shoulders when none are detected in the chest. There are several reasons for this. The bubbles must be large enough so that the reflected ultrasonic waves from the bubbles can be detected over the background blood flow signal. Echoes from smaller bubbles will be lost in the background signal. The background signal is very complex and noisy and consists not only of the signals from blood cells but also from any moving surface within the sound field. This can include the motion of the heart walls and heart valves. Some of the sounds, notably from the valves, may be quite similar to that from bubbles. The subclavian veins, on the other hand, are superficial veins, and the background is relatively quiet. Thus, it is easier to detect bubbles in these locations. Detecting and classifying bubbles with the Doppler ultrasonic bubble detector requires extremely skilled and well-trained observers.

Because not all bubbles can be detected in the chest, it is necessary to look at other locations in the body. With the Kisman-Mansurel method used by DCIEM, both the right and left subclavian veins (shoulders) are always monitored in addition to the chest. Other locations such as the femoral vein or inferior vena cava can be monitored, but the minimum should be the chest and the two subclavian veins.

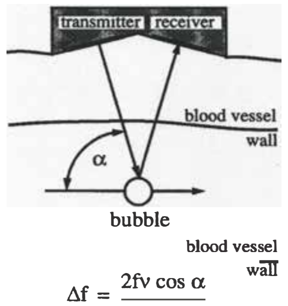
Monitoring is done for two conditions: first, with the diver standing at rest and second, after the diver performs some specific movement. For chest monitoring, the diver performs a deep knee-bend, squatting, then rising again. For the subclavian veins, the diver clenches the fist, then relaxes the hand on the side being monitored.

Previously available Doppler bubble detectors (IAPM, Sodelec and the early versions of the TSI units) operated at 5 MHz. At DCIEM, it was found that with the 5 MHz units it was sometimes difficult to obtain good signals, particularly with large individuals, and that a slight shift in the position of the probe could mean the difference in whether bubbles were detected. DCIEM is now using 2.5 MHz instruments manufactured by TSI. The use of the lower frequency results in less attenuation of the signal by the tissue mass between the bubble and the transducer and in a slightly broader beam width, which makes probe placement less critical.

The Kisman-Masurel code

The method Kisman and Masurel developed for identifying and classifying bubbles consists of breaking the bubble signal into its component parts. The diver is monitored for bubbles while standing at rest, then after performing a specific movement. If bubbles are present, the movement condition generally increases the number of bubbles swept into the circulatory system. The signal is first analyzed by determining the bubble frequency, i.e., the number of bubbles per cardiac period. This is graded on a scale of 0 to 4, 0 representing no bubbles, and 4 representing so many bubbles that they cannot be individually distinguished. The signal is then analyzed, once

WHAT IS A DOPPLER BUBBLE DETECTOR?



$$\Delta f = \frac{2fv \cos \alpha}{c}$$

Named after 19th-century physicist Christian Doppler, Doppler's principle states that the frequency of an observed sound is different from that emitted by the source whenever the observer and the source are moving relative to one another. The classic example of this is an observer standing at a railway crossing waiting for a train to pass. As the train approaches the crossing, the engineer blows the whistle. To the observer, the whistle changes from a high-pitched sound as the train approaches to a lower-pitched sound as the train passes and recedes into the distance.

In the Doppler ultrasonic bubble detector (DUDB), a transmitting element radiates sound at a constant frequency into a blood vessel (see diagram). Sound waves are reflected back by red blood cells. Because the blood cells are moving, the reflected waves, as picked up by the receiving element, are shifted in frequency (Doppler effect). This frequency shift depends on the frequency of the transmitted wave (f), the velocity (v) of the reflecting objects, the angle (a) between the transmitted wave and the direction of motion, and the velocity of sound (c). In fact, the DUDB is actually a flowmeter, which can be used to measure the flow velocity in, for example, blood vessels or pipes.

A gas bubble passing through a blood vessel is a "hard" reflecting object compared to the blood cells due to the differences in density and velocity of sound between the gas and the blood. Thus a bubble produces a significantly higher echo (depending on the size of the bubble) than the background echoes from the blood cells.

Small bubbles may not be detected, because the echoes, although much larger than those from blood cells, may be overwhelmed by the background signal consisting of the combined echoes scattered back by the millions of red blood cells that may be surrounding the bubble. Also contributing to the background signal is the Doppler shift from any other moving object within the sound field, such as pulsating blood vessel walls and, if monitoring in the heart, the movement of heart valves.

Typically, a DUDB operates at a nominal frequency of 2.5 or 5 MHz. Instruments that have been designed for decompression research such as the Techno Scientific DUDB are continuous wave (CW) instruments. (CW instruments are generally less expensive, less complicated and easier to use than pulsed Doppler systems.) The DUDB output is the difference in frequency between the transmitted and received waves. This frequency difference is in the audio range and can be picked up easily using a set of high-quality headphones.

again on a scale of 0 to 4, for the percentage of cardiac cycles containing bubbles for the rest condition, or for the duration, i.e., the number of cardiac cycles with elevated bubble signals, after the movement condition. Finally, the signal is analyzed for the amplitude of the bubble signal relative to the amplitude of the background blood flow signal.

The three parameters—frequency, percentage/duration and amplitude—are then combined into a three-digit code that can be translated into a bubble grade on a scale of 0 to 4 similar to the Spencer scale. Although the KM method may appear to be complicated, it is in fact much simpler to learn, because it treats bubble grading as a systematic procedure. With practice, an individual can classify the three parameters simultaneously and immediately assign the three-digit KM code to the signal.

Doppler Monitoring

The objective of Doppler monitoring is to obtain a history of bubble production for each subject after a dive. For most non-saturation dives, bubbles are not observed until about a half hour after the diver has been on the surface. Delays of an hour or more have also been noted; thus a single monitoring of a dive subject is not sufficient and could result in bubbles being missed. As it is not possible to monitor a single individual continuously, measurements are taken periodically at 20- to 40-minute intervals for at least a two-hour period after the diver surfaces. In stressful dives, bubbles can be observed as soon as the divers surface, and in some cases, the bubbles have been observed to persist at high levels for more than six hours after surfacing.

During the 1970s, the Doppler technique fell into some disfavor, as it became evident that large numbers of bubbles could be detected in many cases with no indication of DCI. In addition, DCI was found to occur in some cases with no detected bubbles. (The latter may have been a result of poor instruments, poor techniques, inadequately trained users, and not looking in the right place or at the right time. In much of the earlier work, bubble monitoring was carried out only once after a dive.) Thus, the original hope of using the Doppler as a diagnostic tool for predicting DCI was not borne out.

Another early hope for the Doppler bubble detector was as a personal decompression monitor to control decompression by listening to the bubbles at the decompression stops. Although bubbles can be detected at the stops for dives requiring substantial decompression, bubbles generally tend to become observable only after the diver has reached the surface. Thus, a Doppler bubble detector is not practical as a personal decompression monitor. In addition, the skill and training required for identifying bubbles would rule out its use for most individual.

Bubble-DCI Correspondence

Several surveys of Doppler data have shown a relationship between intravascular bubbles and DCI. Many of these studies were based on relatively small data sets; however, they all show that the risk of DCI increases with increasing bubble grades. DCIEM has amassed a considerable amount of Doppler data since 1979. This data has been reviewed and analyzed by D. Sawatzky of DCIEM, who selected a data set consisting of 73 cases of DCI in 3,234 man-dives (1,726 man-dives on air/nitrox and 1,508 man-dives on helium/oxygen breathing mixtures) conducted over an 11-year period. All bubbles were classified according to the Kisman-Masurel code.

Figure 1 shows the relationship between percentage DCI and precordial bubble grades observed in the chest for divers standing at rest. For air/nitrox dives, the incidence of DCI is very low for Grade 0 (no bubbles) or Grade 1 bubbles. The risk of DCI increases when bubbles at the Grade 2 or higher levels are observed. In the data set, only one of three subjects was on air/nitrox and one of two subjects was on helium with Grade 4 bubbles. Grade 4 bubbles in the chest with the diver at rest are rare, unless the dive profiles are extremely unsafe. All previous studies have also shown that the risk of DCI in these cases is extremely high.

Figure 2 shows the relationship between percentage DCI and precordial bubble grades after movement (deep knee-bend). The movement condition is convenient, because it generally results in a temporary increase in the number of bubbles observed. For example, some individuals with Grade 3 bubbles in the chest with the diver at rest may have Grade 4 bubbles after movement. For this data set, Grade 4 bubbles were observed in 37 subjects for air/nitrox dives and 132 for helium dives resulting in a 14% and 10% incidence of DCI.

The data presented in Figures 1 and 2 suggest that when bubbles are present, the risk of DCI is higher for air/nitrox dives than for dives conducted using helium/oxygen breathing mixtures. A problem in trying to correlate DCI with precordial bubbles is that DCI sometimes occurs without any precordial bubbles being observed. In this data set, there was a 0.6% incidence of DCI for both air/nitrox and helium dives (7/1,164 subjects and 6/945, respectively) when no bubbles were detected. It should be noted that not all bubbles can be detected in the precordial region. If all sites are considered (the chest and both left and right subclavian veins), and if the maximum bubble grades are observed regardless of site and condition used (i.e., rest or movement), the results show that only one case of DCI (out of 1,442 subjects) had no observable bubbles. Thus DCI is almost always accompanied by bubbles. This shows the importance of monitoring other body sites in addition to the chest.

Of the 3,234 dives in the DCIEM data set presented here, 55% had observable bubbles. Of these, only 4% had DCI. Thus, intravascular bubbles are not a good indicator of which individual will develop DCI. However, almost all the cases of DCI (72 out of 73) were accompanied by bubbles. Therefore, if no bubbles are detected, the risk of that individual developing DCI is extremely low.

Figure 3 shows the percentage DCI results for the maximum bubble grades observed (regardless of location or condition). When the maximum score is considered, it can be seen that the risk of DCI is low for Grades 0, 1, and 2 bubbles and that Grades 3 and 4 have a much higher risk. Over 90% of the cases of DCI were associated with Grades 3 or 4 bubbles.

It should be emphasized that intravascular bubbles are not believed to be the direct cause of the signs and symptoms in all cases of DCI. They are, however, an indicator of a high inert gas load in the body. As a result, their presence reflects the risk of DCI.

Decompression Stress

Of the 3,234 dives in the DCIEM data set presented here, 55% had observable bubbles. Of these, only 4% had DCI. Thus, intravascular bubbles are not a good indicator

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Fig. 1. DCS vs. Maximum Bubble Scores Precordial Bubbles at Rest

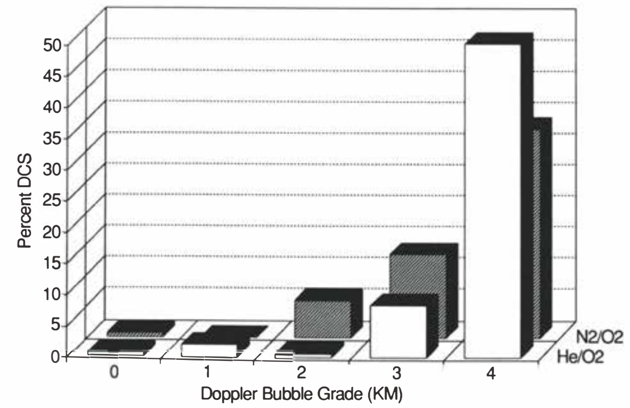


Fig. 2. DCS vs. Maximum Bubble Scores Precordial Bubbles after Movement

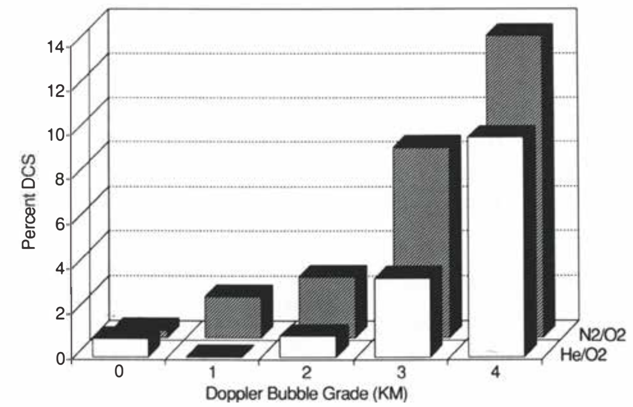
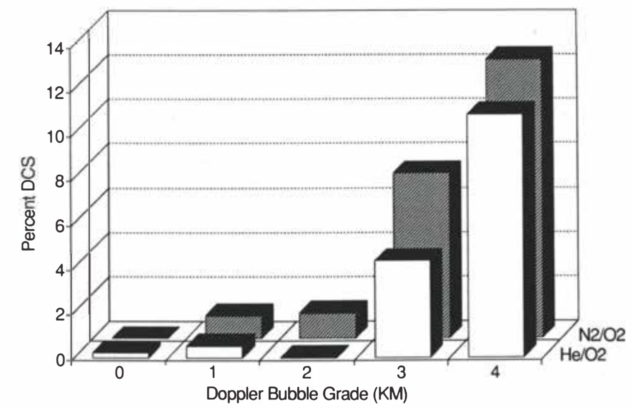


Fig. 3. DCS vs. Maximum Bubble Scores Precordial and Subclavian Sites



corps letters

Is too much knowledge dangerous?

I am a 38 year old pharmacist, working on my Masters degree in medical writing, and am also a PADI and EAN (enriched air nitrox) instructor heavily involved in helping my brother, run a dive store. I have been diving since 1979, and have made about 200 decompression dives, most on East Coast wrecks, and frequently dive solo: a fact of life for an instructor, but also my preference unless I'm working with another diver I trust.

I think you would find it interesting to know that my son, Jim, was certified in EAN last year when he was 13 years old. That should speak volumes to anyone who asks me whether I think technical diving knowledge is mortally dangerous. In fact, I believe the opposite. The reason why recreational diving is restricted to short, shallow dives is because the usual training, techniques and equipment make dives outside "the limits" hazardous. Technical methods on the other hand are being developed by the leading divers in our sport to safely perform challenging dives. Following this thinking to its logical conclusion, recreational divers could profitably use some of these technical methods to make their own dive safer.

My son's diving is a great example of how access to advanced technique can be used to increase diver safety at the recreational level. You ought to see the raised eyebrows he shoots at me when he sees other people wreck diving without a redundant air system, hang tanks, up line, double buckle weight belt, extra lights, and most important, solid dive plans.It doesn't make sense to him.

Observing both Jim's reaction and that of other new divers who have had access to technical diving information has convinced me that it is not a Pandora's box. This is a big change in my position. A few years ago, I would have argued vehemently that this knowledge needs to be guarded. My current belief is that the dissemination of information about technical diving is analogous to the risk vs benefit analysis made in medicine. Doctors don't hesitate to prescribe a drug like penicillin when it's needed, even though a small percentage of the population will have an adverse reaction, even die from taking it. The benefit out weighs the risk. In a similar way the dissemination of technical diving information will help ordinary divers, both technical and recreational dive safer.

Of course, a very small number of people are bound to misuse the information and hurt themselves; that's the risk part of the equation. They will get hurt, not because they used advanced techniques, but because they ignored the rest of the essentials. I believe that the people who would get hurt abusing high tech information would find a way to do a number on themselves anyway— if not in diving, then in a car or somewhere else. They are in it for the risk.

Tom Carroll
New Windsor, MD

Personal responsibility

This is just the kind of publication my dive friends and I have been looking for. And let me emphasize one thing; we accept (the aquaCorps) "Warning Statement" and the philosophy behind it. Personal responsibility and a "level head" is our code too.

Kevin Smith
Corning, New York

Freedom Of information

It is important that the general diving public be exposed to these (technical diving) concepts. It is up to the individual to decide what makes sense for them and what should be discarded. In a free society information should be shared and discussed, not held as a closely guarded secret.

Scott Huffman
Miami, Florida

Submitted by Larry 'Harris' Taylor

Community

For The Rouses

Chris and Chris Rouse Jr. died 12Oct92 as a result of an entanglement that delayed their exit from the submarine, the *"U-Who"*, from which they ultimately were unable to recover. They were NAUI divemasters, and full-cave certified cave divers, who had been presented with the Abe Davis award for more than 100 safely completed cave dives. Chris Sr was also the regional safety officer for the National Association for Cave Diving (NACD). Their credits included dozens of dives beyond two to three hundred feet in Florida caves. Their ocean diving experience was equally varied and spectacular; in 1992 alone they explored the *Andrea Doria* (245 fsw/74 msw), the *"U-Who"* (230 fsw/70 msw) and the *"Oil Wreck"* (175 fsw/53 msw) off the

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of which individual will develop DCI. However, almost all the cases of DCI (72 out of 73) were accompanied by bubbles. Therefore, if no bubbles are detected, the risk of that individual developing DCI is extremely low.

The primary use of the Doppler ultrasonic bubble detector is as a research tool for post-dive assessment of dive profiles. The traditional approach to developing and

evaluating dive tables or profiles has been based on the occurrence or non-occurrence of DCI. From the statistical point of view, proving the safety of dives using DCI as a criterion with any degree of confidence would require more dives than are normally feasible. Moreover, the diagnosis of DCI can be quite subjective. Since intravascular bubbles occur far more frequently than DCI and can be detected even in safe dives, the Doppler ultrasonic bubble detector can provide for more information to assist in the assessment of the severity of the dive profile.

We can speak of "decompression stress" as a criterion for safety. Dives that produce many observable bubbles will have a high risk of DCI and, therefore, high decompression stress. Conversely, dives which produce no

We can speak of "decompression stress" as a criterion for safety. Dives that produce many observable bubbles will have a high risk of DCI and, therefore, high decompression stress. Conversely, dives which produce no observable bubbles or few bubbles will have a very low risk of DCI and low decompression stress.

observable bubbles or few bubbles will have a very low risk of DCI and low decompression stress. In evaluating dive profiles, it is no longer necessary to "bend" divers to know whether the dive profiles are acceptable. (Note the use of the term "observable." The fact that bubbles cannot be detected with the Doppler ultrasonic bubble detector does not necessarily mean that bubbles are not present.)

Simple criteria for estimating the acceptability of dive profiles can be established based on the number of subjects displaying high bubble grades. For example, one criterion to reduce the risk of DCI to less than 5% could be that less than 50% of the subjects have bubble scores of Grades 3 and 4 based on the maximum score observed from all sites and all monitoring conditions (see *Figure 3*). Several complicating factors are the variation in response among different subjects. As with DCI, some subjects are more susceptible to developing intravascular bubbles than others. Also, individual divers can respond differently to similar dive profiles on different days. Thus it is important that a sufficient number of man-dives be carried out on each profile to be tested.

Personal Profiles

Can the Doppler ultrasonic bubble detector be used for personal diving? As described earlier, it cannot be used as a personal decompression monitor to control the rate of decompression. However, there may be a potential for post-dive use. If high bubble levels are detected after a dive, there may be a high risk of DCI, and such dives should be avoided or modified in the future to reduce the risk. With high bubble levels, perhaps some precautionary action could be taken, such as breathing surface oxygen. The movement condition shows that the number of bubbles can increase temporarily; hence, excessive physical exertion should be avoided for several hours after a stressful dive. With high levels of bubbles, the bubbles can persist for many hours after the dive, so flying after diving should be delayed longer than normal. With high bubble levels, the diver should remain in the vicinity of others and remain alert to the possibility of DCI symptoms. It is important that signs or symptoms of DCI not be ignored because no bubbles or only a few bubbles were detected.

The major problem with the use of Doppler for personal diving is the training required to use the instrument correctly and to be able to interpret the Doppler signal to detect and grade bubbles if they exist. It requires a high degree of skill, aptitude and considerable practice working with an expert before any degree of proficiency is acquired. Without this training and skill, there is a great danger of misuse of the instrument and misinterpretation of the signals. Although considerable research has been conducted into automatic systems for bubble detection and analysis, none have been successful because of the complexity of the Doppler signal. Instruments such as the Farallon MacRecorder for the Apple Macintosh, which allow digitization of the Doppler signal and provide an audible and visual representation of the signal, may assist in identifying bubbles but are too simple to be used for automatic bubble detection and classification. Bubble identification and classification are still best done by the human brain.

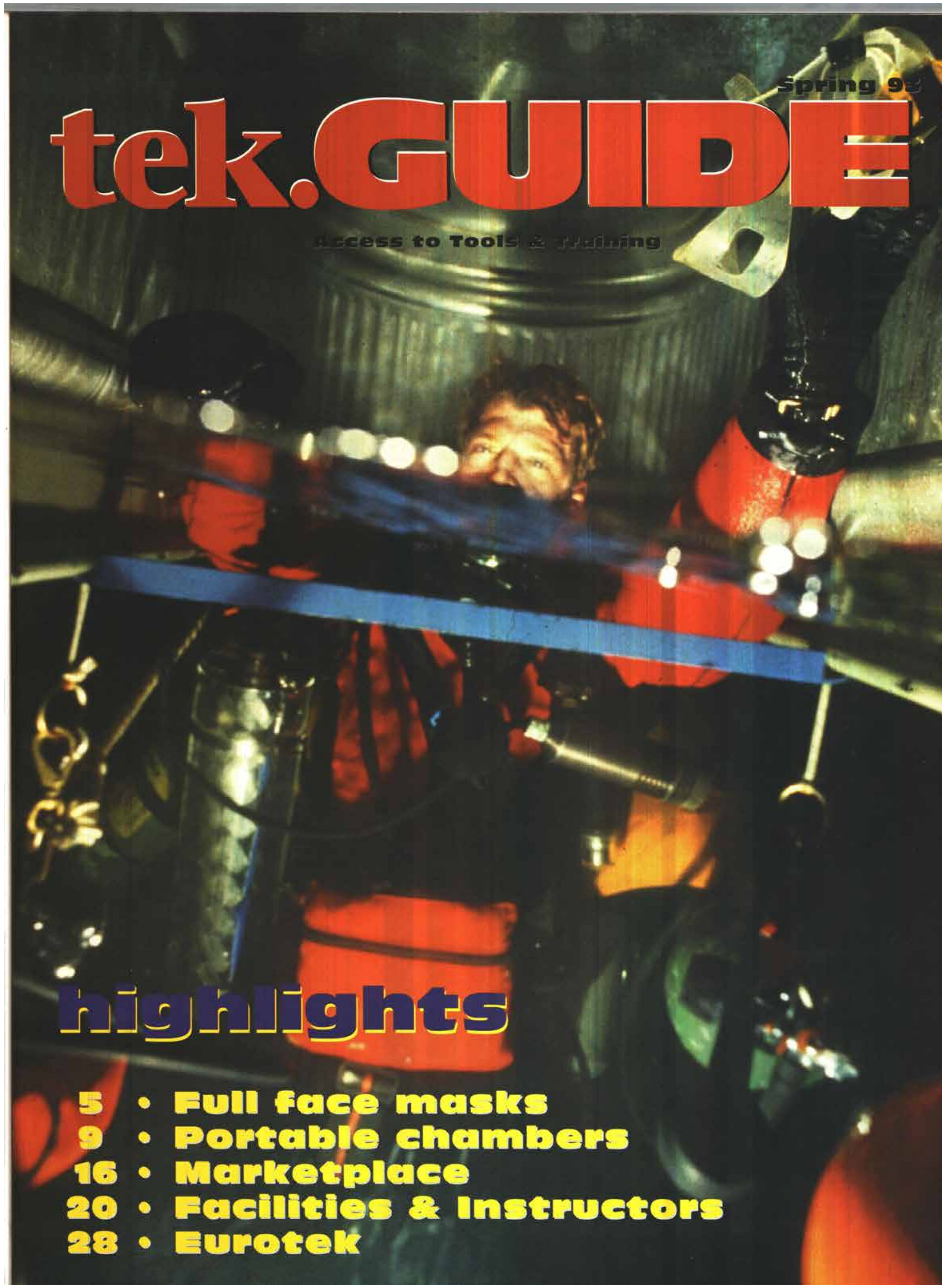
Ron Nishi is the Senior Scientist at the experimental Diving Unit of the Defense and Civil Institute of Environmental Medicine (DCIEM) in Ontario, Canada. His work includes research on the detection of bubbles by Doppler and other ultrasonic techniques, dive computing, decompression modeling and table development. He can be contacted at: DCIEM, PO Box 2000, North York, Ontario, M3M 3B9 Canada. Fax#: 416-635-2104.

Suppliers of doppler ultrasonic bubble detectors

Techno Scientific Inc.
60 Caster Avenue
Woodbridge, Ontario Canada L4L 5Y9

Institute of Applied Physiology and Medicine
701-16th Avenue
Seattle, Washington, USA 98122

Sodelec S.A.
31 Traverse Prat
Pointe-Rouge
13008 Marseille, France



directory index

About the Cover: Parker Turner decompressing in the "Habitrough" at Cheryl Sink.

advertiser index

Bottom photo by Robert Ianello Jim Baden, Scuba Adventures with an AGA mask system. Inset photo: Jim Heggeman, DECA, notice backup mask worn by diver on the right.

Many people believe that full face masks represent the next evolution in open-circuit diving systems due to their many safety and performance benefits. Though none of the existing mask and block systems are specifically designed for technical diving applications, for example with respect to redundancy considerations or gas switching capability, numerous teams are beginning to adapt these systems for extended range diving . Here, former commercial diver and consultant, Steve Barsky, discusses some of the history, basic functionality and benefits of full face masks.

A Close Look at Full Face Masks

by Steven M. Barsky

Full face masks—diving masks that include a breathing system—have become increasingly popular over the past few years with the scientific and search and rescue divers and are now making inroads in the technical community. One of the most important of many reasons for wearing a full face mask is that it permits communications, because the diver does not need to use a mouthpiece. Other advantages include protection of the face from cold water or air temperatures, protection from biological pollution, and a decreased risk of drowning should the diver pass out underwater. Head protectors available for some full face masks can help shield the head from impact injuries underwater.

A BRIEF HISTORY

One of the earliest full face masks in this country is the old Desco free flow mask that was used by Navy and commercial divers. This very simple mask has no regulator—only an "on-off" valve to control airflow to the mask. Air just flows in and exits through an exhaust valve. The mask's triangular shape covers the diver's entire face. Communications with the Desco mask is poor due to the constant hiss of air entering the mask.

The people who truly revolutionized full face mask design were the team of Bev Morgan and Bob Kirby. Morgan was a surfer and early scuba diver. He helped establish the Los Angeles County Underwater Instructor's program, which was the first scuba certification agency in this country. Morgan went on to become a highly successful abalone diver and commercial oilfield diver, and worked in heavy gear on the west coast of the U.S. and in Alaska.

Bob Kirby was a Navy diver who had worked aboard a submarine tender. After he left the Navy, Kirby met Bev Morgan on a commercial diving job, and the two soon found they had common interests. They began designing and building heavy gear helmets in the slack period between diving jobs. Both men also worked to develop full face masks. Morgan realized that a lightweight fiberglass mask would allow a diver more mobility than traditional heavy gear. Together, the two developed the Kirby-Morgan® Band Mask, which became the world's most popular commercial diving mask. It also provided the basis for the development of a diving helmet, the SuperLite-17®.

While Kirby and Morgan worked on commercial designs in the '70s, the Swedish company Interspiro invented a lightweight full face mask. The AGA design represented a different approach to providing breathing gas in hostile environments. Interspiro's mask was designed to work for both firefighting and diving.

During the '50s, the Widolf mask also appeared, with yet another compact design. The Widolf mask was a ruggedly built mask, but did not approach the comfort of the band mask or the AGA.

On the low end, both Cressi Sub and U.S. Divers offered simple, rubber full face masks. Both of these masks had provisions to accept a standard scuba regulator, but neither had an integral breathing system. In addition, neither had provisions for any communications.

In the mid 1980s Bev Morgan began developing a lightweight full face mask that could be used for both scuba and surface supplied diving. His company, Diving Systems International, came up with a new lightweight mask known as the EXO-26®. The design team for the mask consisted of Morgan, Skip Dunham (president of Diving Systems International), Pete Ryan, and Tom Protheroe. The name "EXO" is derived from the exoskeleton that forms the mask frame and supports the face seal.

FULL FACE MASKS TODAY

The two main choices for technical divers for full face masks today are the AGA and the EXO-26®. Both masks have excellent breathing systems, and both provide good communications. Choosing between the two is not easy, and you should dive with both before you make a decision as to which one to buy. Every piece of diving gear has its advantages and disadvantages. When you choose one piece of gear over another, you are basically deciding which set of compromises you can accept.

The common features of all the more sophisticated full face masks, such as the AGA and EXO, include a face seal, a lens, a mask frame, a head harness or "spider," a regulator and an oral-nasal mask. The oral-nasal mask covers the mouth and nose. It provides an acoustical chamber for speech and cuts down the dead air space in the mask to help prevent CO_2 build-up.

THE AGA MASK

The AGA mask has many outstanding characteristics. Although the mask originally was excessively buoyant, the lens was redesigned several years ago to help reduce this problem. The AGA features a no-return valve in the breathing system that helps reduce the possibility of inhaling contaminants when diving in polluted water.

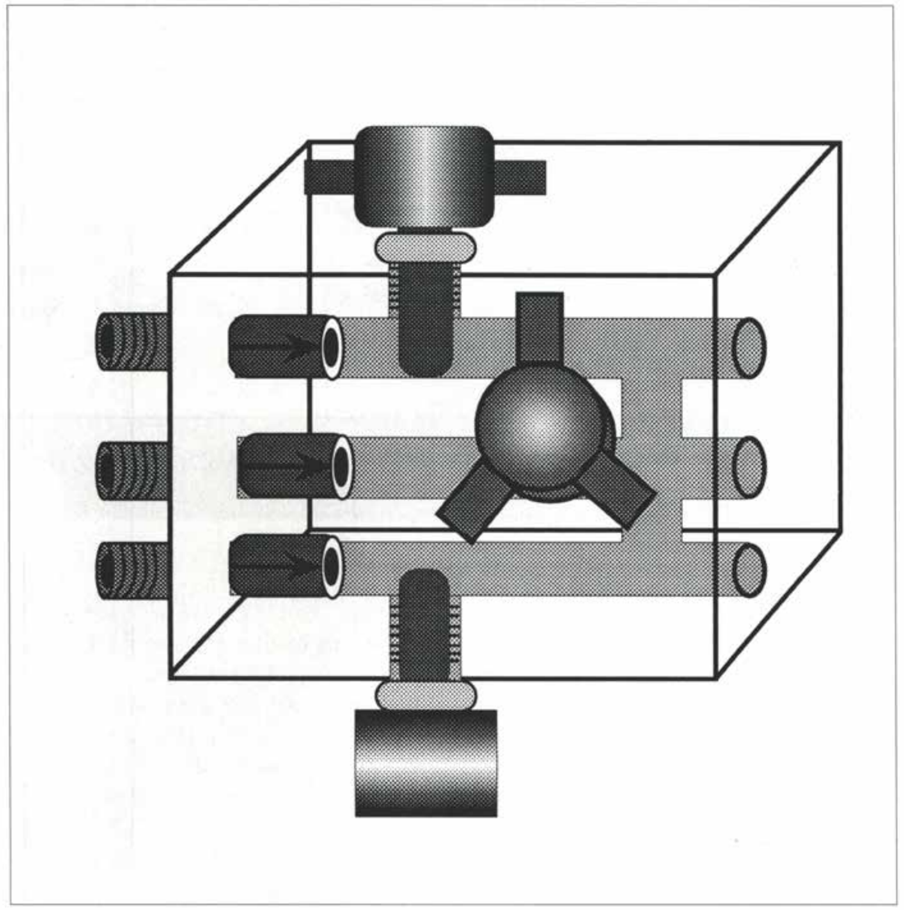
Equalizing your ears is easy with the AGA due to a simple, yet effective equalizing device which consists of a rubber pad on a clip. By adjusting the height of the pad, it is easy to block your nose by sliding the mask upward on your face.

The AGA's breathing system has been designed to defog the mask automatically each time you take a breath. When you inhale, the regulator flows the gas across the lens to help keep the mask clear. The breathing system was a top performer during tests at the Navy Experimental Diving Unit (NEDU).

Finally, the AGA has what is known as a positive pressure breathing system. As long as the mask is sealed against your face the AGA functions as a regular demand breathing system. However, if you break the face seal on the mask, the AGA will go into a freeflow mode. If the seal is only partially opened, this will help to keep the mask from flooding. If the seal is completely broken and the mask is pulled away from your face, the positive pressure system will help you to clear the mask very quickly of any water. Clearing is almost instantaneous.

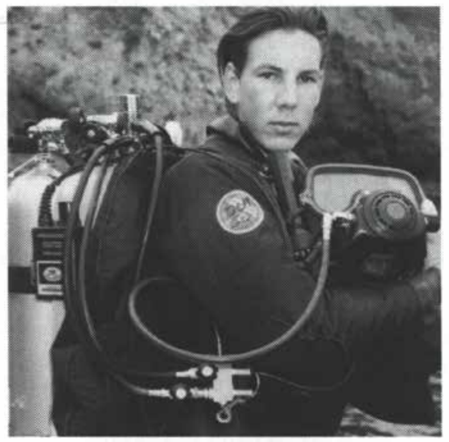
The AGA mask works for both firefighting and diving, but it has certain drawbacks from trying to fulfill its dual roles. In terms of its overall design, perhaps the most serious problem is the AGA's high internal complexity. The regulator alone consists of 45 separate parts, with another 28 parts in the mask and oral-nasal mask. The AGA requires eight different special tools to service it. The AGA is not the type of mask that can be readily serviced in remote locations when all you have is a butter knife to make repairs.

Diving with the AGA reveals a few other drawbacks that some divers will find more objectionable than others. First, the



head harness, or "spider," is very flimsy. It works, but it doesn't have the rugged feel you would like it to have if you're deep or way back inside a wreck. It would be nice if it were two or three times as heavy.

Secondly, the AGA lacks earphone pockets. This is a serious drawback, as one of the main advantages to a full face mask



is that it permits communications. While various communications equipment manufacturers have designed methods for attaching earphones to the straps on the AGA, the arrangements are not as good as a set of integrated earphone pockets.

Finally, the AGA's microphone is positioned in the very front of the mask, just above the regulator. There is nothing "wrong" with this location, but it can make wire routing for communications systems awkward. In addition, if you are working in low visibility, and you must get close to see what you are working on, this arrangement is somewhat vulnerable to damage and entanglement.

THE EXO-26® MASK

The AGA was built to be a multipurpose mask; the EXO was built from the bottom up for diving. It has several features that are found on no other full face mask.

Unlike the AGA, the EXO-26® has an absolute minimum number of parts, 56 to be exact, compared to the AGA's 73. The EXO regulator has only 36 parts compared to the AGA's 45. Only one special tool is required to work on the EXO's regulator, and standard tools will service the rest of the mask. The special regulator spanner is a stamped metal tool that is included with purchase.

The EXO regulator has separate inhalation and exhaust chambers, with the exhaust compartment surrounding the inhalation chamber. The large exhaust port helps reduce exhalation resistance. This design uses your exhaled breath to help warm the incoming gas—a real advantage if you dive in very cold water. It also helps prevent contaminants from entering the breathing system and producing a spray. The EXO mask did not exist when the Navy conducted their regulator tests in 1985 and 1986.

Breathing resistance on the EXO can be adjusted by the diver at depth with the regulator adjustment knob. This system is the same one used on both the Kirby-Morgan® band mask and the SuperLite-17® to depths of 1,600 fsw/520 msw. It also appears on the new SuperLite-27®. To clear a flooded EXO, push the regulator purge button.

Communications with the EXO are very good and especially convenient to use. The microphone is part of a special modular system that can be replaced very rapidly. It is located on the lower right side of the mask, behind the regulator hose attachment.

Earphone pockets are built into the face seal and provide a reliable carrying position for the earphones. It is easy to slide the earphone speakers in and out of the pockets.

Heavy duty straps and buckles complete the EXO-26. They have a beefy feel to them and don't act like spaghetti when you pick the mask up. They provide extremely rapid adjustment for the mask, both topside and underwater.

Of course the EXO mask, too, has some drawbacks. Generally speaking, its automatic defogging system is not quite as good as the AGA's. When you inhale with the EXO, the gas actually enters the mask from the top through a special breathing tube that connects to the regulator. The gas then flows down the lens for inhalation through the nose and mouth. While the theory behind this system is good, in actual practice most divers find that they will want to carry a tube of Prell shampoo with them to soap the inside of the lens prior to diving. Just apply a tiny dab of Prell and wipe the lens with a soft cloth until the shampoo nearly disappears. This will keep your lens clear while you are underwater.

A nose pocket on the EXO is supposed to allow you to equalize your ears just as you would in an ordinary scuba mask. Although this arrangement works well in warm water, it doesn't work for cold water diving with thick gloves. If your diving takes you to colder waters, you will need to purchase a special equalizing device to help you block your nostrils.

The AGA and the EXO are priced within $5 of each other, so the real issue comes down to personal preference. Both were priced near $700 in 1992. If you shop around, you can probably get a deal, especially if you buy communications at the same time that you buy your mask.

Try both masks. Just as no one scuba mask will fit everyone, neither the AGA nor the EXO is for every diver. You need to decide which one you prefer.

DIVING WITH FULL FACE MASKS

As with any piece of gear, you should get specialized training before you use full face masks in an operational situation. Initial training should take place either in a pool or a confined open water environment under optimal conditions.

Before using the mask, you should be completely familiar with it. In particular, you should know how to don and remove the mask by yourself, and how to clear the mask should it flood. Obviously, it is impossible to breathe from a full face mask if it is full of water!

In an out-of-gas emergency, gas sharing with a full face mask is very awkward. The moment you remove the mask, you are essentially blind. Each time the mask is passed from user to user, it must be cleared of water, a procedure that requires far more air than clearing an ordinary scuba regulator. This is not a satisfactory arrangement. Under these circumstances, it is preferable to have a separate scuba regulator integrated with your system and to carry an ordinary face mask. This equipment can also serve as a back-up in the event that the full face mask fails for any reason.

If you are diving deep, in an overhead environment, or doing decompression diving, you should carry a back-up gas supply when using a full face mask. The back-up supply should be connected to a manifold block, also known as a "bail-out block". This block is usually positioned on the diver's harness, on the right side, at chest level. Diving Systems International manufactures a bail-out block that can be used for technical scuba diving but is more suited to surface supplied diving.

Figure 1 illustrates a possible arrangement for a bail-out block that might be better suited to technical diving. The block contains three non-return valves, so that should any one of the low pressure supply hoses fail, the breathing gas would not be lost in the ruptured hose between the first and second stage. There are three on-and-off valves in this block, and all are shape and color coded. The valves should have some sort of positive "locking" system to ensure that they won't be accidentally opened. The first valve is for the main supply, the second valve is for a second gas mix, and the third valve is for the bail out. There are enough ports to accommodate a dry suit, a full face mask, and a back-up regulator. Of course, some divers may prefer to use an independent suit inflation or argon system with their dry suit.

As an additional back-up, you can also install a quick-disconnect fitting

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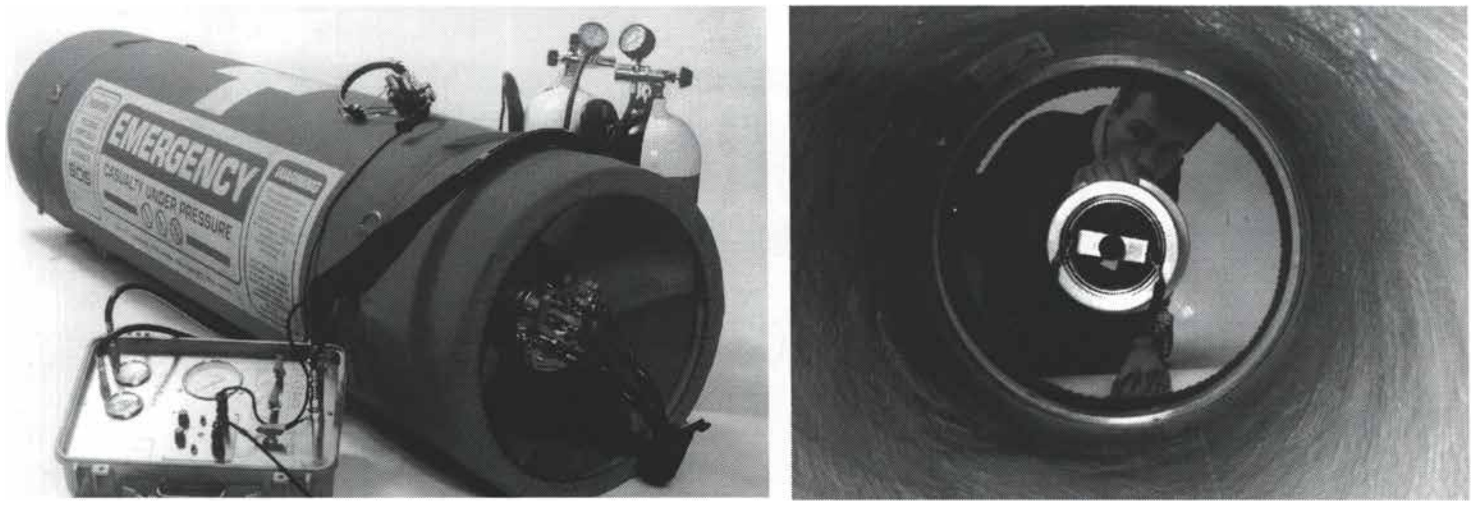


SOS Ltd.'s Hyperlite Portable Chamber

Portable Chamber TECHNOLOGY

by John Selby

Having a chamber on site has simply not been feasible in most cases, though its value would be hard to dispute given the kind of demanding diving that is often conducted by these groups.

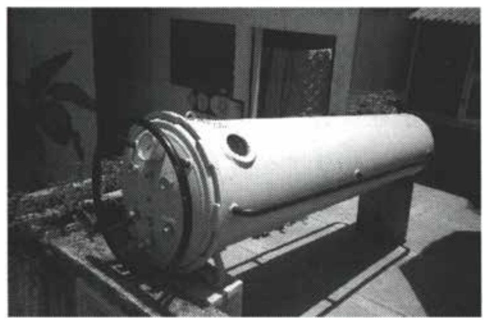
Five years ago, SOS Limited of London, set about to develop a radically new type of recompression chamber designed to address the problem of emergency field treatment for divers suffering from acute decompression illness. Today it is well known that if the diver can be put back under pressure immediately without delay, then the chances of residual injury are negligible. Failing that, the chances of permanent brain or spinal cord damage escalate with the time to treatment. Though in-water oxygen therapy has been used with success, in the absence of a accessible chamber, putting a stricken diver back in the water is rarely desirable if there are other alternatives.

Though an on site chamber is a requirement for most commercial and military diving operations, this is not the case in sport and scientific diving. Having a chamber on site has simply not been feasible in most cases, though its value would be hard to dispute given the kind of demanding diving that is often conducted by these groups.

What SOS has tried to do with the development of the Hyperlite chamber is to produce a low cost, very lightweight "transport" chamber, that is easy to use and can be set up in less than five minutes. In the event of a DCI incident, the diver in question can be immediately pressurized up to 60 fsw (2.8 atm) and oxygen therapy begun, while transportation to a hyperbaric facility is arranged. The entire chamber along with an attendant can then be transported by helicopter, boat or car to the appropriate treatment center.

Note that the Hyperlite should not be considered a treatment chamber. Therapies can of course be conducted in it, especially when it is used in remote places, where transfer to a therapy chamber is logistically or geographically impossible. However, it is designed primarily as a transport chamber, or hyperbaric stretcher if you will, a first aid device for divers at a time when every minute counts.

Figure 1



Traditional Steel Monoplace Chamber
Photo: Bret Gilliam

Comparison to traditional mono-place chambers

To appreciate some of the unique features of the Hyperlite it is useful to review some of the background and characteristics of traditional mono-place (one person) chambers, which it was designed to replace.

Mono-place chambers, sometimes referred to as "iron coffins," are manufactured by rolling and welding aluminum or steel sheet which produces a good leakproof pressure retaining shell. The problem is that such chambers are bulky, heavy, expensive and cannot be easily transported, or stored when not in use. Most are very dark inside having a very small six inch window (hence the name "iron coffin") for the patient to see out, which often results in claustrophobia and sometimes panic in the patient. See Figure 1.

Typically these chambers are equipped with some form of lock-on device so that they can be coupled to a therapy chamber with a compatible flange. The problem is that there are so many different types and sizes of flanges that mating to a therapy chamber is often more a matter of luck than of design. Ugly problems can occur if this transfer, for whatever reason, can not take place.

When using a monoplace chamber, the patient breathes the chamber gas, usually air for treatments to 165 fsw (6 atm), or oxygen (2.8 atm) which results in a build-up of carbon dioxide (and/or oxygen). This means that the chamber has to be regularly flushed which consumes considerable amounts of gas. Alternatively, if there is a CO2 scrubber, heavy batteries are needed in the absence of main power. Though a Built-In-Breathing System (BIBS) is available for mono-place chambers, they are not the norm.

The Hyperlite chamber differs from metal mono-place chambers in several important ways. First of all, the Hyperlite uses modern Kevlar-based composites to replace heavy steel or aluminum. Like a car tire, the chamber tube is totally rigid under pressure, but when it is deflated it can be folded into a box one quarter of its length long. Each end of the chamber is enclosed by a full diameter acrylic window, which gives the patient a wide outside view and the medical attendent a clear view of the patient.

In addition, the Hyperlite utilizes a BIBS system to overcome the problems of CO2 and O2 build-up.

As a result of its construction, the Hyperlite can be folded and stored in two small carrying cases and transported out to the dive site. Once pressurized, with a patient inside, the chamber can easily be carried by a maximum of four people to suitable transportation, and the entire unit with the operator can be evacuated to the nearest therapeutic multi-place chamber. At the facility, immediate transfer under pressure is essential so that the patient can be treated without delay by qualified personnel. For that reason, the Hyperlite is designed to pass directly through the door of most chambers without the need for a flange. Therapy chambers usually have a minimum door size of 24 in., while the Hyperlite has an outside diameter of 23.5 in. Once inside, the therapy chamber can be pressurized and the patient can be transferred out of the unit.

Treatment depth

As an emergency transport chamber, the Hyperlite is designed to provide oxygen therapy at working pressure of up to 60 fsw (2.8 atm), suitable for a USN Table 5 or 6. Though air treatments to 6 atm (165 fsw), for example the USN Table 6a, are still used in the case of barotrauma and what used to be referred to as "Type II" decompression sickness, increasingly, the primary treatment for most cases of DCI is pressurization to 2.8 atm (60 fsw). This is a considerable advantage with respect to the Hyperlite, in the case that the patient loses consciousness, stops breathing, or becomes incapacitated in some other way as discussed below.

Removal of a patient under pressure

At pressures greater than about 2.8 atm (60 fsw), the immediate removal of a patient from a mono-place chamber is very much a last resort situation. At these pressures the patient will have been on air or nitrox. To reduce pressure to atmospheric quickly will almost certainly result in further decompression problems. In extreme cases this has resulted in a fatality. That is another reason why the 6 atm (165 fsw) one-man chambers were called coffins.

Because the Hyperlite chamber only operates at pressures of up to 2.8 atm (60 fsw) using oxygen, treatment will have been initiated as soon as pressure is applied. In the event that the removal of the patient becomes necessary, this can be accomplished by returning the chamber to surface pressure at the normal ascent rate of 60 fpm. Thus the elapsed time until a patient can be removed from the chamber is less than 90 seconds. Provided that the patient has been under pressure on oxygen, nitrogen levels should be greatly reduced and the chances of reoccurrence of DCI should be lower.

Construction and operation

Having established the reasons for developing the Hyperlite chamber and some of its principal features, it may be useful to discuss its construction and how the unit is operated.

The tube shaped body of the chamber is made from a composite of Dupont Kevlar 49 fibers, filament wound in a matrix of silicone rubber. Kevlar, which is used in bullet proof vests, was chosen for its strength and the fact that it does not stretch under load. Silicone rubber is very flexible, inert, has low fire, smoke and toxicity properties, resists ultraviolet light and is easy to clean. Neither material suffers from degradation during storage over long periods of time.

The tube incorporates identical seals at each end. The two full diameter acrylic windows are inserted by deforming the flexible tube ends just enough to allow the windows to go in at right angles to their final position without touching the ends of the tube. One of the windows incorporates the necessary penetrations for the various supplies to the chamber, while a medical lock can be installed in the other, if required, so that food, drink and medication can be passed to the patient.

Sealing the chamber on initial pressurization is accomplished by turning on the air supply while pulling the two end windows away from each other. This is easily accomplished. Once the initial seal has been achieved, no further pulling is necessary as the higher the pressure, the tighter the seals become.

The only remaining piece of equipment is a control box that is very simple to operate. It has only three main control valves, a gauge to read chamber pressure, and incorporates a full intercom system to allow two way communication.

The unit has two connectors, one for oxygen and air supplies, and a set of connectors for the umbilical that connects the control box to the chamber. All connectors have built-in non-return valves so that if they are disconnected for any reason, no pressure losses occur. The patient inside the chamber breathes through a BIBS mask which supplies oxygen or air on demand. Note that most protocols require the patient to breathe oxygen for twenty minutes followed by a five minute air break.

Chamber pressure is supplied by a scuba cylinder and requires approximately one half of a standard cylinder (about 40-50 cf.) to achieve maximum operating pressure. Breathing air for the air cycles during therapy uses the same air source. An additional filtration system is available on the air supply line to protect the oxygen BIBS system from contamination.

To complete the package, the entire chamber folds away into a custom built lightweight sealed case. It is so small in fact that the chamber can be checked in as personal baggage at the airport, usually without excess fares being charged.

Testing and certification

The Hyperlite chamber has been subjected to very extensive testing and certification procedures. The initial prototypes were subjected to pressure and cycle testing. Although it is very unlikely that the chamber would be used daily, a unit was subjected to over 16,000 cycles from zero to a maximum pressure of 70 fsw (3.1 atm) over a ten day period. This is equivalent to four treatments a day for a period of ten years. No damage to the seals was detected. The chamber was also subjected to low temperature operation to insure that the flexibility of the composite did not restrict the setting up and pressurizing of the equipment.

More recently at the request of the ASME Pressure Vessels for Human Occupancy (PVHO) committee, a burst test was conducted on a production unit. The chamber started to break down and lose pressure at 426.5 fsw (13.9 atm), or 6.2 times the maximum working pressure of the chamber (70 fsw). Metal chambers simply do not have that safety margin. These tests were followed by drop tests with sand bags to simulate the weight of a patient. The chamber was dropped at a 45° angle through a distance of 3 feet on a rough concrete surface without damage.

Eventually, like its commercial diving counterpart, *"having a chamber on site"* may become a "consensus standard" in the technical community. Given the level of diving that is likely to be conducted in the future, the question will become," Can you afford not to have one?"

The Hyperlite is currently certified by Lloyd's register and has clearance for sale in the U.S. by the FDA. No additional approvals are required by law, even though the chamber is still undergoing ASME PVHO approval, a lengthy exercise, as the code relates to fixed hospital chambers made of weldable materials.

The future of portable chambers

Priced at around $30,000 U.S., the Hyperlite chamber represents a significant cost reduction over steel or aluminum mono-place chambers which run in the neighborhood of $125,000 U.S. plus. Nevertheless, this cost is still high in terms of widespread use among technical divers.

With acceptance by insurance carriers, entrepreneurial leasing and service providers, and with volume, the price of having a portable chamber on site is likely to fall putting it within the reach of dive operators, resorts and clubs. Eventually, like its commercial diving counterpart, *"having a chamber on site"* may become a "consensus standard" in the technical community. Given the level of diving that is likely to be conducted in the future, the question will become," Can you afford not to have one?"

A chartered engineer, John Selby is the founder and Managing Director of SOS Ltd. which manufactures and distributes equipment designed to improve diving safety. Selby can be contacted at: SOS Ltd., Po Box 328, London NW7 3JS, England. Fax: 44(81)959-7971.

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between your primary first stage and your full face mask and between your back-up regulator and first stage. If your diving partner's gear is set up the same way, in the event of a primary first stage failure, you could, theoretically, disconnect your mask from your primary and connect to your partner's secondary mix or bail-out.

Prior to diving with the mask in open water, you should give some thought to the type of diving that you do and how you will use the mask. If your diving normally requires surface swims where you use a snorkel, realize that you will not be able to do this. You will want to remove the full face mask during surface swims to conserve your air. As an alternative you can always remove the full face mask to swim on your back on the surface.

Keep in mind that most of the more sophisticated full face masks, like the AGA or EXO, can be used with a surface supplied diving system. There are several lightweight , relatively inexpensive surface supplied systems available today. Surface supplied diving is much safer than scuba diving in many situations.

Once you have learned how to use the full face mask properly and have gained some experience diving with it, you will find that you don't have to make any radical changes in your diving techniques. Keep in mind, however, that most divers find that their gas consumption with a full face mask is slightly higher, particularly if they are using it with a communications system.

Several wireless communications systems are available, and most will work with any full face mask. A wireless system will help increase your safety, allowing you to communicate with other wireless-equipped divers as well as with those topside, if your dive boat carries a topside unit. Providing facilities for communications is one of the primary benefits of using a full face mask, so you're missing one of the major advantages if you don't include this as part of your system.

Making the switch

If you're diving under demanding conditions, you should definitely consider a full face mask. Commercial divers wouldn't consider diving with anything less. For technical divers, the full face mask can increase your safety, productivity and fun. Just be sure you get the proper training from a professional instructor, so you understand the mask and know how to use it properly.

Steve Barsky is the founder and principal of Marine Marketing and Consulting, a marketing firm serving both the commercial and sport diving industries. A former commercial diver and author, Barsky has published several books on diving technology, while his articles have appeared in a variety of publications. He can be contacted at: Marine Marketing and Consulting, 1628 Hillside Rd., Santa Barbara, CA 93101. Fax: 805-682-1956.

A Word on Wireless Communications

Today's wireless systems are more reliable and offer better performance than the systems that existed just a few years ago. Single sideband is the main technology employed by all the current manufacturers, and the communications are very good.

Basic components of an electronic underwater communications system include some type of full face mask equipped with an oral-nasal cavity and electronics. The electronics are carried in a waterproof housing, normally about the size of a box of band-aids. There are connections for the microphone and earphones.

In selecting an electronics package, there are many features to consider. If at all possible, try the system out in the type of environment you will be diving in on a regular basis.

Set up the wireless unit , ensuring that it has a good attachment point and that wires are routed to avoid snags. Excess lengths of wire should be bundled together. Never attach the electronics box to your weight belt. If you need to ditch your belt, and the electronics are attached to it, you could find yourself in a dangerous position. The transducer/receiver should be mounted where it is not covered by other equipment.

Some systems are equipped with "lollipop" style earphones/speakers, designed to be worn under or over a diving hood. Never place these speakers directly over the ear opening, but instead, in front of or behind the ear. Placing the speakers directly over the ear opening could result in an ear squeeze.

When using wireless, it is important to speak slowly and distinctly in a normal tone of voice. It should not be necessary to shout while communicating. When you are sending or receiving a signal you should minimize your exhalation, but never hold your breath.

tek.GUIDE Marketplace

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PO Box 30070, Santa Barbara, CA 93130
Contact: Abe Schyrer
p: (805)568-3647 f: (805)962-6033
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Senerdyne Ltd.
Station Approach Fleet, Hants GU13 8QY, U.K.
Contact: Peter Holt
p: 44(252)624-955 f: 44(252)628-008
Acoustical locating equipment

CAVE DIVING TRAINING & CERTIFICATION

Commission Provence De Plongee Souterraine (CRPS)
125 rue Jaubert, 13005 Marseille, France
Contact: Claude Touloumdjian

National Association For Cave Diving
Po Box 14492, Gainesville, FL. 32604
p: (904)877-8196

National Speleological Society-Cave Diving Section (NSS-CDS)
PO Box 950, Branford, FL. 32208

CLOSED CIRCUIT SYSTEMS

Carmellan Research Ltd.
11 Hillside Close, Ellington, Huntingdon,
CAMBS. PE18 0AR, England
Contact: Stuart Clough
p/f: 44(480)890-946

Cis-Lunar Development Laboratories
1 Ridgeway Dr., Chadds Ford, PA 19317
Contact: Richard Nordstrom
p; (215)388-2739 f: (215)388-2813

CLOSED CIRCUIT SYSTEMS

National Draeger
101 Technology Dr., Pittsburgh, PA. 15275
Contact: Russ Orlowski
p: (412)788-5688 f:(412)787-2207
Oxygen and mix closed circuit systems

Dragerwerk AG
Auf dem Baggersand 17, D-2400 Lubeck-Travemunde 1
Germany
p: 49(4502)8353 f: 49(4502)8383
Oxygen and mix closed circuit systems

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Contact: John Griffiths
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Structural Composites Industries
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Contact: Steven Anthony
p: (714)594-7777 f: (714)594-3939
Composite cylinders

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Unit C11, Acre Business Park,
Reading, Berkshire RG2 08A, U.K.
Contact: Kevin Gurr
p/f: 44 (365) 869-185
Desktop decompression software

Cybertronix
3435 Redbud Dr., Knoxville, TN 37920
Contact: Corey Berggren
p: (615)579-2434
Desktop decompression software

Dive Rite Mfrg. Inc.
Rt 14, Box 136, Lake City, FL. 32055
Contact: Lamar Hires
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Sheck Exley
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Hamilton Research Ltd.
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Contact: Dr. R.W. Bill Hamilton
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LifeGuard Systems
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Contact: Gain Wong
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Underwater Applications Corporation
427-3 Amhearst St. Suite 345, Nashua, NH 03063
Contact: Randy Bohrer
p/f: (508)433-6586
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p; (305)294-7177 f: (305)294-7612

Seahorse Technical Systems Inc
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Softech House, Osborn Mews, Windsor, SL4 3DE, U.K.
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Thermal protection systems, argon suit inflation systems
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Contact: Steve Linton
p: (303)482-0887 f: (303)482-0893
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Diving Systems International
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Costa Mesa, CA 92626
Contact: Mike Pellisier
p:(714)754-7848 f: (714)966-1639
Wireless communications systems

Orcatron Manufacturing
10186 North Bend St.
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International Association of Nitrox Divers
1545 NE 104th St.
Miami Shores, FL. 33138
Contact: Tom Mount
p/f: (305)751-4873
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p: (516)546-2030 f: (516)546-6010
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Nashua, NH 03063
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London SW19 6EX
Contact: Simon Moores
p: 44(81)789-0961 f: 44(81)780-2018

American Academy of Underwater Scientists (AAUS)
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p: (409)740-4540 f: (409)740-0857
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p: (301)571-1821 f: (301)571-1815
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PO Box N-142, Nassau, Bahamas
Contact: Monty Doyle
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Deep diving, EAN and trimix

U.K. WRECK DIVING:

See "Eurotek" section pg. 28-30

TROPHIES & AWARDS

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Facilities and Instructors

Technical resources

The following guide lists diving facilities offering special mix, equipment, supplies and training. The letter, "A" represents an *American Nitrox Divers Inc.* affiliated center, "E" represents the *European Association of Technical Divers*, and "I" represents an affiliation to the *International Association of Nitrox Divers Inc.*" A list of instructors is also included. The designation, "N" represents enriched air, "nitrox," instruction, "T" represents instruction in trimix and/or heliox, "IT" represents "instructor trainer."

Training Notice:

Training programs for the use of enriched air nitrox with scuba equipment are fairly well established, though there remain a number of open issues regarding mixing and handling practices. At the present time, a consistent set of internationally agreed upon guidelines for enriched air mixing are being developed but are not yet in place. The situation with respect to helium mixes is much different.

The use of trimix and heliox in self-contained diving is in an embryonic stage of development. To date there have been roughly 600-1000 of these dives conducted in the U.S. by approximately 100-150 individuals (see "Trimix Report" in the coming issue of technicalDIVER 4.1 to be published in March,1993—ed.) As a result, there is currently no consistent set of community-accepted training or operational standards for these mixes, and practices vary widely.

Though trimix certification programs exist; they presently lack substance, and though there are qualified instructors, many individuals offering training in mix have minimal experience with this technology and the operational considerations involved. As a result, the quality and content of available training varies considerably.

Warning: We strongly recommend that you investigate a facility and or instructors thoroughly before investing in a training program. Ask for training credentials (who they have trained with, when and where), relevant logged experience (number of relevant dives, number of courses taught), and get references from others who have attended their programs.

Remember, "You, and you alone, are responsible for your safety."

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Hyperbarics International
490 Caribbean Dr., Key Largo, FL, 33037 305-451-2551, I
Forty Fathom Grotto
Ocala, FL, 34478 call Elton 904-368-7974, I
Steamboat Dive Inn
PO Box 1000, Branford, FL, 32008, 904-935-DIVE, I
Branford Dive Center
PO Box 822, Branford, FL, 32008, 904-935-1141, I
High-Tech Diving Adventures
4564 Atlantic Blvd., Jacksonville, FL, 32207
904-398-1274, I
Aquifer Dive Center
4564 Atlantic Blvd., Jacksonville, FL, 32207,
904-398-1274, I
Florida State University at Tallahassee
Academic Diving Program R-7410
Montgomery Building, Tallahassee, FL, 32306,
904-644-3450, I
Gulf Coast Pro Dive
7203 Hwy. 98, West Pensacola, FL, 32506,
904-456-8845, I
The Scuba Shop
348 SW Miracle Strip Pkwy. #19, Fort Walton Beach, FL
32548-5364, 904-243-1600, I
University of Florida at Gainesville
Dive Officer Robert Millott, PO Box 12547
Gainesville, FL, 32604, I
Ginnie Springs Dive Center
7300 NE Ginnie Springs Rd., High Springs, FL, 32643
904-454-2202, I
Diver's Oasis Scuba Center
1512 S. Woodland Blvd., DeLand, FL, 32720, I
Hal Watts' Mr. Scuba
2219 E. Colonial Dr., Orlando, FL, 32803
407-896-4541, I
Private Divers
4840 N. Courtaney Pkwy., Merritt Isle, FL, 32953
407-453-4564, I
Key West Diver
MM 4.5 US #1 Stock Island, Key West, FL, 33040
800-873-4837, "A, I"
Hall's Diving Center & Career Institute
1994 Overseas Highway, Marathon, FL, 33050, I
Ocean Diving Schools
750 E. Sample Rd., Pompano Beach, FL, 33064
305-943-3337, I
Quality Diver Education
1545 NE 104th St., Miami Shores, FL, 33138
305-754-1027, I
Underwater Unlimited
4633 LeJeune Rd., Coral Gables, FL, 33146
305-445-7837, I
Pisces School Of Dive
781 Fairport Road, Coral Gables, FL, 33146
305-445-7837, A
The Diving Educators of Key Biscayne
PO Box 557012, Miami, FL, 33155, 305-361-5222, I
H2O Scuba160
Sunny Isles Blvd., North Miami Beach, FL, 33160
305-956-DIVE, I
National Academy of Police Diving
12074 South West 117th Terrace, Miami, FL, 33186, A
Brownie's Third Lung
940 North West 1st St., Ft. Lauderdale, FL, 33311, A
Bahamas Nitrox Diving Center Ltd.
c/o Dive Dive Dive Ltd., 323 S.E. 17th Street #519
Ft. Lauderdale, FL, 33316, 809-362-1401, A
American Dive Center
1888 NW 2nd Ave., Boca Raton, FL, 33432
407-393-0621, I
Action Aquatics
800 Florida Ave., Tampa, FL, 33604, 813-932-3895, I
Jim's Sea Dive Center
1051 Combee Rd., Lakeland, FL, 33801
813-667-1121/1433, I
The Dive Station
15065 McGregor Blvd., Ft. Myers, FL, 33908
813-489-1234, I
Bay Point Dive Center
300 NW Highway 19, Crystal River, FL, 34428, I
Seahunt Dive & Travel
3395 East Bay Rd., Largo, FL, 34641, 813-539-0227, I

EASTERN UNITED STATES

East Coast Divers:
1) 280 Worcester Rd, Framingham, MA, 01701
800-649-3483/508-620-1176, I
2) 237 Falmouth Rd., Hyannis, MA, 02061
800-698-3483/508-775-1185, I
Northeast Diving Technology
41 Beacon St., Boston, MA, 02108, I
3) 213 Boylston St., Brookline, MA, 02146
800-649-2757/617-277-2216, I
Underwater Applications Corp.
427-3 Amherst St.#345, Nashua, NH, 03063
508-433-6586, I
Hi-Tech Center
211 Hackensach St., Woodridge, NJ, 07075
201-666-0908-IAND, I
Treasure Cove Divers
327 South Ave., Westfield, NJ, 07090, I
"Country Scuba, Inc."
114 Lakeside Ave., Lake Stockholm, NJ, 07460
201-697-0287, I
Sea Dwellers of New Jersey
132-A Broadway, Hillsdale, NJ, 07642, I
Sea Dwellers of New Jersey
132-A Broadway, Hillsdale, NJ, 07642, 201-539-0009, I
Chatham Watersports
9 N. Passaic Ave., Chatham, NJ, 07928, 201-635-5313, I
North Atlantic Technical Services
92 Route 10W, East Hanover, NJ, 07936, I
Triton Divers of L B I
342 West 9th, Ship Bottom, NJ, 08008, 609-494-4400, A
The Gas Station Inc.
831 Charles St., Gloucester, NJ, 08030
609-456-4316, "A, I"
Hi-Tech Divers
831 Charles St., Gloucester, NJ, 08030, 609-456-4316, I
The Dive Shop Of New Jersey
266 Delsea Drive, Sewell, NJ, 08080, 609-589-2434, I
Dive Boat "Diversions"
ATTN: John Comly, 281 Timberline Place
Brick Town, NJ, 08723, I
B&B Divers
588 Shadey Ln, Toms River, NJ,08753, 908-929-4160, A
Enchanted Diver
259-19 Hillside Ave., Floral Park, NY, 11004
718-470-6858, "A, I"
All American Sport Shop
Utica, NY, 11315, 315-733-9282, A
All American Sport Shop
27 North Broad St., Norwich, NY, 113815
607-334-5277, A
"Island Scuba Centers, Inc."
74 Woodcleft Avenue, Freeport, NY, 11520-6132
516-546-2030, A
Professional Diver Training
2 Edgebrook Land, Monsey, NY 10952, A
Dive Inc.
1 South Central Avenue, Valley Stream, NY, 11580
516-872-4571, A
National Diving Center
4932 Wisconsin Avenue N.W., Washington, DC, 20016,
202-363-6123, A
Carroll Scuba
2027 Suffolk Road, Finksburg, MD, 21048
301-833-3638, A
Scuba Hut
139 Delaware Ave., Glen Burne, MD, 21061
301-761-4520, I
Tidewater Aquatics
1147 S. Salisbury Blvd. #7, Salisbury, MD, 21801
410-742-1992, I
Rudee Inlet Dive Center
1091 Norfolk Ave. #107, Virginia Beach, VA, 23451
804-425-2997, I
Lynnhaven Dive Center
1413 N. Great Neck Rd., Virginia Beach, VA, 23454
804-481-7949, I
University of North Carolina at Wilmington
Center for Marine Science - NURC7205
Wrightsville Ave., Wilmington, NC, 28403, I
Full Sail Scuba
211 Richland Ave., Aiken, SC, 29801, 803-642-5411, I
American Scuba Center
1925 Piedmont Circle, Atlanta, GA, 30324, I
Divers Supply
200 Governor Treulen Dr., Pooler, GA, 31322, I
Submariner Research
Box 1906, Bainbridge, GA, 31717, 912-246-9349, I
Louisville Dive Center
2478 Bardstown Road, Louisville, KY, 40222, I
Ocean Tech
7 Stone Tree Rd., Bath, ME, 04530-9401
207-442-0998, I
Scuba Instruction and Development
"Route 4, Wild Acres", Clinton, TN, 37716
615-457-9643, I
Fantasy Scuba Center
115 N. Locust Hill Drive, Lexington, KY, 40509
606-454-2202, I

WEST AND MIDWEST UNITED STATES

Scuba Quest Sport Diving Center
3017 N. Causeway Blvd., Metairie, LA, 70002
504-834-8243, I
University of California-Santa Cruz
Santa Cruz, CA, 95060 408-459-4286, A
Underwater Dive Center
42551 N. Ridge Road, Elyria, OH, 44035, I
Aqua Specialists
14813 Madison Ave., Lakewood, OH, 44207
800-747-8782/216-521-4858, I
University of Michigan
"Dive Officer Lee Somers, Ph.D.", Space Research
Building Ann Arbor, MI, 48109, 313-769-1862, A
Underwater Outfitters
2579 Union Lake Road, Commerce Township, MI, 48382
313-363-2224, I
Michigan Technical Diving Academy
254 River Avenue, Holland, MI, 49423, 616-392-3300, I
D.I.V.E. Systems
1812 Taft Ave., Berkeley, IL, 60163, I
Diventures
1017 W. Diversey Parkway, Chicago, IL, 60614
312-348-3483, I
The Great American Diving Company
467 Lantana Lane, Saint Peters, MO, 63376
314-926-2092, I
Diver's Equipment Scuba Center
5800 Barrymore Dr., Kansas City, MO, 64134
816-763-5678, I
Boiling Springs Dive Center
Route 2 Box 1, Licking, MO, 65542, 314-674-2043, A
Texas Technical Divers
102 Roanoke St., Victoria, TX, 77904, 512-572-2468, I
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8502 N. Black Canyon Hwy, Phoenix, AZ 85051, A
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272 South Fries Ave., Wilmington, CA, 90744
310-834-2501, I
Scuba Adventures
965 South Mt. Vernon Avenue, Colton, CA, 92324
714-825-2502, I
Scuba Adventures Unlimited
253 E. Redland Blvd., San Bernardino, CA, 92408
714-825-2502, I
Adventures In Diving
31678 Coast Highway, South Laguna, CA, 92629, A
Flying Dutchman Hyperbarics
PO Box 3956, Mission Viejo, CA, 92690, 714-380-7462, I
Aquarius Dive Shop
2240 Del Monte Avenue, Monterey, CA, 93940
408-375-1933, A
Aqua-Tech Engineering
3254 Park Lane, Laffeyette, CA, 94549, A
Bodega Marine Lab-Univ of CA
P.O. Box 247, Westside Road, Bodega Bay, CA, 94923
707-875-2032, A
Adventure Sports
303 Potrero St. #15, Santa Cruz, CA, 95060
408-458-3648, A
Ocean Oddessy

2345 South Rodeo Gulch, Santa Cruz, CA, 95062
408-475-3483, I
University Of California-Davis
Davis, CA, 95616, 916-754-1419, A
Bellingham Dive and Travel
720 West Maplewood, Bellingham, WA, 98225
800-388-6341, "A, I"
Pacific Reef
7516 27th St. West, Tacoma, WA 98466, A

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Epic Divers
45781 Kamehameha Hwy., Kanohe, HI, 96744
808-236-IAND, I
Hawaiian Divers
4-5490 "B" Kaiwi St. (PO Box 3515)
Kailua-Kona, HI, 96745, 800-356-2243/808-329-2243, I

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High Tech Divers Ltd.
PO Box 813, Lane Cove, New South Wales,
2066, Australia, 02-427-1274, I
IAND of Australia
255 Stanmore Road, Stanmore, New South Wales,
2048, Australia, I
Nassau Scuba Center
"F. Nivens, Coral Harbour Beach Club & Villas",

PO Box CB11863, Nassau, Bahamas
809-362-1964/800-327-8150, I
Stuart Cove's Nassau Undersea Adventures
Box CB11697, Nassau, Bahamas, I
Sunskiff Divers
PO Box N-142, Nassau, Bahamas, 809-362-1979, I
Kingston Diving Center
786 Bath Road, Kingston, Ontario, K7M 4Y2, Canada
613-634-8464, A
Tim's Place
RR 2, Minesing, Ontario, L0L 1Y0, Canada, I
Gildenburgh Water
Estrea Road, Whittlesey, PE7 2AR, England U.K.
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IAND Affiliate European Association of Technical Divers
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574 Kingston Road, Raynes Pk SW20 8DR,
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CEDAM Dive Center
AP 117 Playa del Carmen, Quintana Roo
Mexico, 52-987-35129, I
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P.O. Box 305G Palmdale, Grand Cayman B.W.I., A
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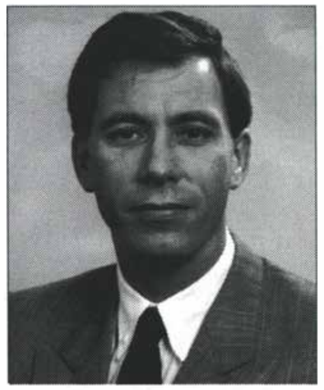

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Welcome to Eurotek.

With the burgeoning interest and development of technical diving in Europe, we will be expanding our coverage to include this important segment of the self-contained diving community.

Beginning with this report from our European editor, Simon Moores, look for more features and information in future issues of the Journal and technicalDIVER. M[2]

Editorial

EuroScuba: Politics and Paradox

by Simon Moores

"Surrounding every technology are institutions whose organization— not to mention their reason for being— reflects the world-view promoted by that technology. Therefore, when an old technology is assaulted by a new one, institutions are threatened. When institutions are threatened, a culture finds itself in crisis."

Neil Postman
Technopoly: The Surrender of Culture to Technology

The British diving scene presents a curious contrast to anyone looking in from the outside. On the one hand there is a vibrant adventurism and dramatic examples of technological innovation in areas such as C^2 (closed circuit) breathing systems, "desktop decompression" and portable chamber technology. Meanwhile, at the opposite end of the spectrum, the sport suffers from what is perhaps an over-cautious streak of conservatism where new ideas are involved, together with the ever present risk of government involvement if the conduct of the sport is not kept in order.

The British Sub-Aqua Club (BSAC) is the dominant force in U.K. recreational diving. With over 50,000 members, the organization offers one of the most thorough and inexpensive diver training programs in the world. As a result of size and probably its club structure, the BSAC is much more of a reactive organization than a pro-active one. As a consequence, new ideas are slow to filter through the committee stage before they are accepted. This situation prompted a recent American visitor to observe that, *"the typical British sport diver is probably better trained than his or her U.S. counterpart, where as the leading U.S. technical divers are light years ahead of the leading U.K. divers in terms of technology and technique."*

BSAC's reticence to move quickly has left the U.K. recreational market open to the approaches of an increasingly aggressive and market aware PADI, which is enjoying tremendous growth in the U.K.. PADI correctly recognizes that not all British divers enjoy the sometimes rigorous challenges of British Isles diving. Indeed, there are many thousands of resort divers whose needs are not being served, and 1993 will, I have heard, see PADI attempting to promote their own club concept in direct competition with BSAC. So much for recreational diving.

Thanks largely to aquaCorps, the expression, "technical diving," first surfaced on our shores two years ago, and has been a source of growing interest and some debate ever since. With probably more ship wrecks available for diving than anywhere else in the world, Britain sports a corps of very experienced divers who for the most part have been limited to air diving. Most of these individuals are conducting these operations without the benefit of the methods and equipment such as in-water oxygen decompression, wings and harness systems, in some cases even *doubles*, which is taken for granted by leading U.S. wreck and cave divers. In addition there is a need for improved "operational support," a concept which is only now starting to catch on in the States. Interestingly enough, enriched air ("nitrox") diving is still considered a part of the "technical" venue in the U.K., and in terms of commercialization, is probably a year and a half or two behind the U.S.

Similar to the initial positions taken by the recreational agencies in the States, BSAC's reaction to the use of enriched air and other special mixes has been largely predictable. Though BSAC insists that it offers "technical diving" skills at its higher levels of training, it rejects many of the latest operational methods which have become "community standards" in the States. Not surprising, at its recent Diving Officers Conference, BSAC choose not to endorse enriched air diving as a club-sanctioned activity. However with the newly formed British training association, the European Association of Technical Divers (EATD), and both of the U.S. enriched air training companies, ANDI and the IAND, actively developing European operations; it's probably only a matter of time, before enriched air diving gathers sufficient commercial impetus to achieve a broad base of support.

To be sure, over the last six months, the U.K. has suffered from the same kind of misinformation blitz that has been so rampant in the States. Comments such as *"oxygen and nitrogen will separate in an enriched air mixture," " nitrox divers can't be treated in a chamber,"* and *"trimix is only for warm-water diving,"* only serve to confuse an intelligent audience that is hungry for information. Here, as in the USA, "nitrox" is regarded as "controversial" in some circles, and there are those who fear that hapless recreationalists will become "hooked" on the "devil gas." As a result, serious divers find themselves turning to the thriving underground for information on techniques and equipment, because the home grown editorial is inclined to feature more politically acceptable subjects.

That is not to say that there isn't legitimate cause for skepticism and a need to improve these fledgling service offerings. Similar to the U.S., the enriched air contingent still has its fair share of problems, including developing a consistent set of acceptable mixing standards and procedures, which remains a hot issue in the States, local politics, and in the case of British diving, receiving an exemption from commercial regulation, similar to that granted to sport diving training, from the government's Health and Safety Executive. It is hoped that with the dissemination of better information, in conjunction with cooperation among the various technical product and service organizations, these issues can be successfully addressed, and the U.K. will make the conceptual leap into the nineties and beyond.

So what does the future hold for European diving? It's likely that the U.K. will serve as a gateway for new ideas and methods which will inevitably filter through the continent. European divers may not have thought of themselves as technical, but have made some remarkable explorations and penetrations without the benefit of much of the technology and methods enjoyed by top U.S. divers. Inevitably, as they have elsewhere, more divers will start using doubles, back-mounted BCDs, improved decompression methods and special mix, which will open an exciting new chapter in underwater wreck exploration, caving and underwater archeology.

Given it's penchant for entrepreneurship, the U.K. is also likely to serve as a springboard for much of the new technology that will eventually be adopted by this market, whether its British-style training programs, Carmellan's new closed circuit system, Aquatronics' decompression software or SOS Ltd.'s field treatment chamber. Access to enriched air technology is the first step on the ladder of progress.

Clearly the challenge for Britain's emerging technical community is to take a leadership role by offering an avenue for interested users to improve their diving safety and performance. This can best be achieved through cooperation and the commitment to provide timely and accurate information and high quality instructional programs. Safety is the first priority.

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More information...

More information on Doppler detection of bubbles may be found in:

Butler, B.D., Robinson, R., Fife, C. and Sutton, T. (1991). Doppler detection of decompression bubbles with computer-assisted digitization of ultrasonic signals. Aviat. Space Environ, Med. 62:997-1004.

Eatock, B.C. (1984) Analysis of Doppler ultrasonic data for the evaluation of dive profiles. In Underwater Physiology IX, Proceedings of the Ninth International Symposium on Underwater and Hyperbaric Physiology. pp. 183-195. A.A. Bove, A. J. Bachrach and L.J. Greenbaum Jr. (Eds.), Bethesda, MD: Undersea and Hyperbaric Medical Society.

Evans, A. (1975). Ultrasonic surveillance of decompression. In The Physiology and Medicine of Diving and Compressed Air Work, 2nd Edition. pp. 417-434. P.B. Bennett and D.H. Elliott (Eds.), London: Bailliere, Tindall.

Nishi, R.Y. and Earock, B.C. (May 1989). The role of ultrasonic bubble detection in table validation. In The 37th Undersea and Hyperbaric Medical Society Workshop, Validation of Decompression Tables. UHMS Publication 74(VAL) 1-1-88, pp. 133-137. H.R. Schreiner and R.W. Hamilton (Eds.), Bethesda, MD: Undersea and Hyperbaric Medical Society.

Nishi, R.Y. (1990). Doppler Evaluation of Decompression Tables. In Man in the Sea, Volume I. pp. 297-316. Y.C. Lin and K.K. Shida (Eds.), San Pedro, CA: The Best Publishing Co.

Powell, M.R., Spencer, M.P. and von Ramm, O. (1982). Ultrasonic surveillance of decompression. In The Physiology and Medicine Diving (Third Edition), pp. 404-434. P.B. Bennett and D.H. Elliott (Eds.), San Pedro, CA: Best Publishing Co.

Sawatzky, K.D. and Nishi, R.Y. (1991). Assessment of inter-rater agreement on the scoring of intravascular bubble signals. Undersea Biomed. Res. 18 (5-6):373-396.

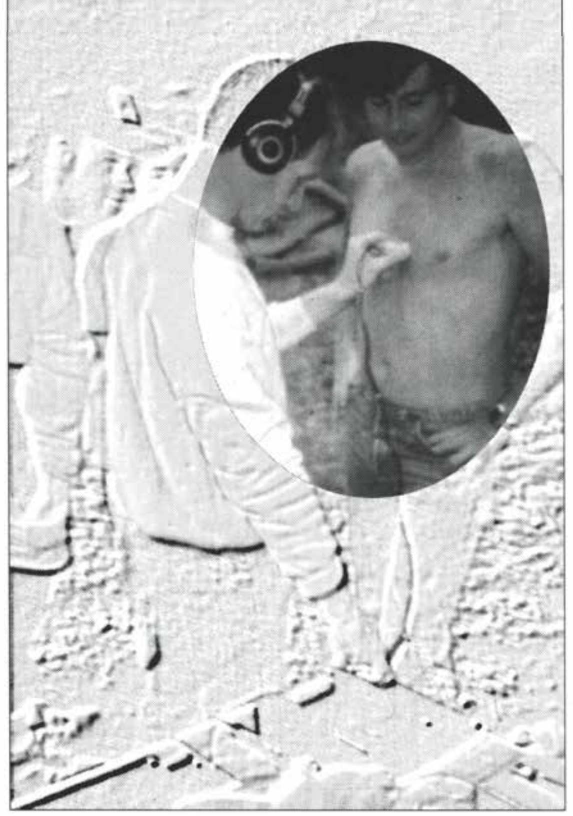
Spencer, M.P. (1977). Doppler ultrasonic detection of venous gas emboli (VGE). In Proceedings of the Twelfth Undersea Medical Society Workshop Early Diagnosis of Decompression Sickness. UMS 7-30-77, pp. 1-49. R. Pearson (Ed.), Bethesda, MD: Undersea Medical Society Inc. (Note: there are a number of other papers in this reference devoted to early work in Doppler.)

KEEPING SCORE

By Jim King

"One more minute and I will smash this "bug" to smithereens. Ouch. ""Flex. " Thirty seconds and the "bug" will be dead. Ten. Five. Three. Two. One. Smack.

Photo by Michael Menduno



Jim King dopplering Dustin Clesi after a dive to 360 fsw (110 msw) for 40 minutes at Diepolder II, Brooksville, FL.

"Bug wars" are always memorable when using doppler in the field. The person being "dopplered" must flex at 30 second intervals and cannot often smack **"bugs"** at will. If weather conditions are humid, hot and the ground is wet, or the boat is rocking, Florida can be a difficult area for field doppler at almost any time of the year.

Why doppler? As our team began to do more and more deep mix exploration dives, we immediately realized several conditions would need to be met if we were to validate our decompression procedures.

First, we needed a consistent team of people with an established baseline for comparison. Second, we felt that a consistent matrix, or table set, which could be matched to our dives, should be used and adhered to as closely as possible, hence our use of DCAP *(a computational algorithm designed by Dr. R.W. Bill Hamilton, Hamilton Research Ltd.—ed.)*. Finally, we needed a method of determining how well the dive team responded to the decompression tables. Doppler monitoring seemed to be the best alternative.

Our approach was relatively simple; use DCAP to prepare the tables, dive the tables, record and analyze the results. Initially, safety "pads" were used in our decompression computations. After gaining confidence with a particular series of dives, we found that we could dive the tables the way they were designed to be dived—to the limits. However we continued to apply caution; if the dive were unusual for any reason, or if our "bubble scores" were high, the "pads" would go back in. Doppler told us how well divers were responding to a particular dive, or a certain table, on a given day.

Bugs not withstanding, one of the important things we learned about using doppler, was to have the same person score the results if at all possible. Scoring is somewhat subjective, so in order to remain as consistent as possible, we used the same person to score the tapes. These are used only once and are kept as a permanent record with the results (doppler score), copy of the tables used, and dive profile. Good records are essential for meaningful results.

Having monitored over a hundred dives, we feel this work has been important in validating the use of DCAP and developing a reliable set of procedures for trimix diving, though we still don't really know where the "edge" is. None of the team has been bent, though we've probably been close. Our team has seen high three's and four's on some long deep dives, which we've learned is not atypical for these types of exposures. You have to find your own limits.

The USN Treatment Tables

by John Zumrick

Though other procedures and methods have evolved, the U.S. Navy treatment tables have become a standard of reference for treating decompression illness. Here, naval medical officer, Dr. John Zumrick describes USN procedures and some of the history and thinking behind them.

For the technical diver, dives have become longer and deeper, with many approaching or exceeding the limits of traditional decompression tables. Tables used to manage these exposures are less thoroughly tested than those of more limited and, therefore, more common dives, so it is reasonable to expect the incidence of decompression illness (DCI) to be higher. Moreover, owing to variations in individual physiology, even commonly used decompression schedules are not entirely bends free. As a result, a technical diver runs a higher-than-normal chance of experiencing a case of DCI *(Note that the overall estimated decompression risk for sport divers is about.02% or "one in 5000 dives," though the risk for extended range dives is probably higher. See* "Decompression Safety," *by Richard Vann, pg.13).*

Recompression therapy is the definitive treatment for DCI. Begun shortly after the onset of bends, recompression can result in dramatic, almost immediate improvement and cure, even while the diver is still being compressed to treatment depth. Delayed therapy, however, is far less successful in effecting a cure and may require multiple treatments.

Since the 19th century, bubble formation has been implicated as the cause of decompression illness. DCI is caused by an excessively rapid lowering of ambient pressure. This reduction in pressure results in inert gas dissolved in tissue and blood coming out of solution and entering the gas phase, causing bubbles to form in tissue and blood. Signs and symptoms of bends can be grouped into two broad categories based upon their severity.

In traditional terminology, "pain only," or Type I, decompression sickness encompasses the relatively minor forms of the syndrome and includes limb pain, lymphatic manifestations and skin manifestations. Limb pain is the most common symptom of DCI, occurring in about 90% of USN cases. *(Based on recent incident data from DAN and others, more than half the sport diving cases reported have neurological involvement—ed).* This pain involves the arms and shoulders in a majority of cases and varies in intensity from a mild, nearly imperceptible ache to steady, nearly unbearable pain. The exact mechanism by which bubbles cause this pain has not been determined, but it is thought that pain that responds to position is caused by local bubbles within the tendons and ligaments around joints, while deep boring pain that does not respond to movement, may be due to increased pressure in the longbones. Lymphatic manifestations are thought to be caused by bubbles blocking lymph flow resulting in swelling. Skin manifestations can also occur, which include itching, rash and purple mottling, usually over the trunk and back.

Classical "Type II decompression sickness" is normally neurological, but does include "chokes" and extreme fatigue. Presenting signs and symptoms of these DCI manifestations are shown in Figure 1 to the right. The mechanisms by which bubbles produce the neurological manifestations are not well defined, either, though it is thought that bubbles trapped within and blocking pulmonary arteries may account for chokes.

Elliott and Hallenbeck have elucidated the mechanism of spinal cord decompression sickness in dogs. Normally, blood flow throughout the spinal cord and adjacent epidural vessels is slow but adequate. Increases in central venous pressure due to bubbles in the pulmonary artery contribute to reduction in blood flow through the spinal cord and epidural vessels. Bubbles may also form within these vessels, reducing blood flow. Blood-bubble interface may lead to platelet adhesion and the release of other chemical substances, which themselves may reduce blood flow. The resultant reduction in blood flow results in tissue hypoxia leading to paralysis. Thus, although DCI is initiated by the formation of inert gas bubbles, it is a manifestation of additional pathologic changes, particularly when not treated early.

Prior to 1937, the U.S. Navy utilized treatment Table 1, based on never allowing the inert gas tension in the body's slowest "tissue compartment" to exceed twice that of ambient pressure. In 1937, Yarborough and Behnke shortened Table1 by including oxygen breathing at a depth of 60 fsw (18 msw) or less. The Behnke Yarborough modification of Table 1 included recompression to 165 fsw (50 msw) for 30 minutes, followed by 90 minutes of breathing oxygen at 60 fsw (18 msw). The end result was a saving of 45% of decompression time from the original table.

In 1945, Van der Aue standardized recompression therapy in the U.S. Navy. His procedures formed the basis for treatment Tables 3 and 4 *(Note that these tables are "still on the books" but are seldom used today due to their length, the operational difficulties involved, and their perceived ineffectiveness. See discussion below.—ed.).* The tables included initial recompression to 165 fsw (50 msw) for 30 to 120 minutes; an overnight soak on air at depths shallower than 60 fsw (18 msw) for 12 to 24 hours; and the use of 100% oxygen at 60 fsw (18 msw) or less. Unfortunately, operational use of these tables between 1946 and 1961 yielded a treatment failure rate of nearly 30%.

In 1965, Goodman and Workman proposed changes to these tables that formed the basis for the current oxygen treatment tables, Tables 5 and 6. They eliminated the initial recompression to 165 fsw (50 fsw) in cases of pure decompression sickness and lengthening of the oxygen breathing periods at 60 and 30 fsw (18 and 9 msw). Recompression to 165 fsw (50 msw) was reserved for cases of arterial gas embolism. The initial experience with these tables indicated a failure of less than 9%.

Current USN treatment methods incorporate two separate goals: 1) the immediate reduction in bubble size and 2) permanent bubble resolution.

Immediate recompression effects immediate reduction in bubble size, but the practical effect of this is limited. Assuming for the moment that gas bubbles are spherical, recompression to 66 fsw (20 msw) reduces a bubble to 1/3 of it's volume at sea level pressure, while recompression to165 fsw (50 msw) reduces it to 1/6 of it's original volume. Further recompression to 198 fsw (60 msw) reduces the bubble to only 1/7 of surface volume, an insignificant difference compared to its volume at 165 fsw (50 msw). Thus recompression deeper than 165 fsw or 50 msw is thought to be therapeutically insignificant, particularly when taking into account the effects of narcosis, additional gas loading, and the resulting extremely long decompression times.

Recompression produces an immediate reduction in bubble size favoring restoration of circulation and reduction of bubble effects in tissue. However, once this initial reduction in bubble size has been achieved, additional inert gas uptake by the bubbles may actually favor later bubble growth.

To promote bubble resolution, high partial pressures of oxygen are used. When 100% oxygen is breathed, blood inert gas tension is reduced to zero, creating a high gradient for the elimination of inert gas from bubbles and from the body. Recompression to only 60 fsw (18 msw) therefore produces two advantages. Recompression increases inert gas tension within the bubble, and oxygen breathing reduces the blood inert gas level thereby increasing the gradient and thus maximizing the elimination of inert gas and bubble resolution. Additionally, the body takes up no additional inert gas while oxygen breathing. This reduces required decompression time.

The above discussion assumes that bubble resolution occurs in a medium where tissue blood flow is fast, effectively carrying away the inert gas liberated from the bubble. However, in cases where tissue blood flow is reduced, such as spinal cord DCI, bubble resolution may be limited by the rate gas is carried away from the tissues by circulation rather than by gas diffusion from the bubble.

In addition to promoting more rapid bubble resolution, oxygen has other therapeutic advantages. Oxygen provides better tissue oxygenation to areas where blood flow may not be adequate, thereby reducing tissue injury. Finally, oxygen has been shown to have an anti-swelling effect on nervous tissue, which may be useful, particularly in cases of spinal cord DCI.

TREATMENT TABLES

Though there are a variety of approaches and tables that are used successfully today by those involved in treating DCI, the U.S. Navy uses two types of treatment tables: 1) those using hyperbaric oxygen breathing in relatively short treatments 2) and those employing air breathing throughout treatments of relatively long duration *(Note that with the advent of oxygen therapy, air treatments have "fallen out of favor" in the non-military community, and are viewed as not very effective in most instances—ed.).*

In most cases when oxygen is available, the oxygen breathing tables (Tables 5, 6, and 6A) are strictly preferred to the air-breathing tables (Table 4). The oxygen tables have several advantages. First, bubbles resolve more quickly during oxygen than air breathing. Second, hyperbaric oxygen reduces central nervous system edema. As a result, these tables are more effective in treating cases in which treatment has been delayed *(common in sport diving incidents—ed.);* whether this improvement is due to the anti-edema effect or to the improved tissue oxygenation is unclear. Oxygen-breathing tables are also shorter than traditional air tables. This gives patients who need other hospital care access to therapy that cannot be administered while in the chamber. Finally, the patient may be decompressed at any time from an oxygen table without worsening symptoms, because the tissue absorbs no additional inert gas during treatment.

Treatment Table 5, which was once described as a *"carrot to lure the diver into the chamber"* is intended for the treat-

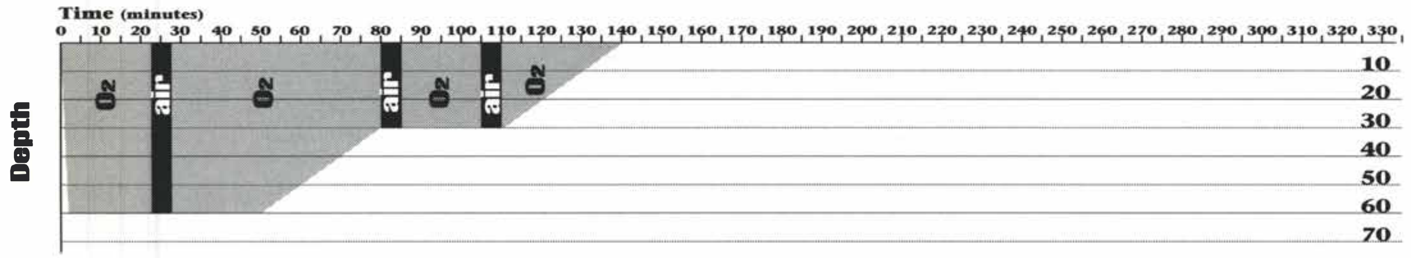
F1 Presenting signs and symptoms of DCI manifestations

Pulmonary Decompression Sickness (Chokes)	Substernal chest pain usually burning in nature. Coughing, frequently uncontrollable. Shortness of breath.
Neurologic DCS Brain Involvement	Headache usually severe. Visual changes. Confusion, behavior changes. Paralysis - usually of one side of body, must distinguish from air embolism.
Spinal Cord DCS	Weakness and paralysis of legs. Loss of bladder and bowel control. Numbness or changes in leg sensation, called paresthesias.
Inner Ear	Ringing in the ear. Deafness. Dizziness (vertigo).
Shock	Decreased blood pressure due to loss of fluid from the blood vessels into the tissues.
Body Pain	Pain of the back, abdomen, or chest as opposed to limb pain.
Fatigue	Extreme fatigue far beyond that expected for the amount of exertion expended.

To convert feet to meters divide feet by 3.265.
See aquaCorps Letters "Corrections: Getting it Right" page 57.

USN Table 5

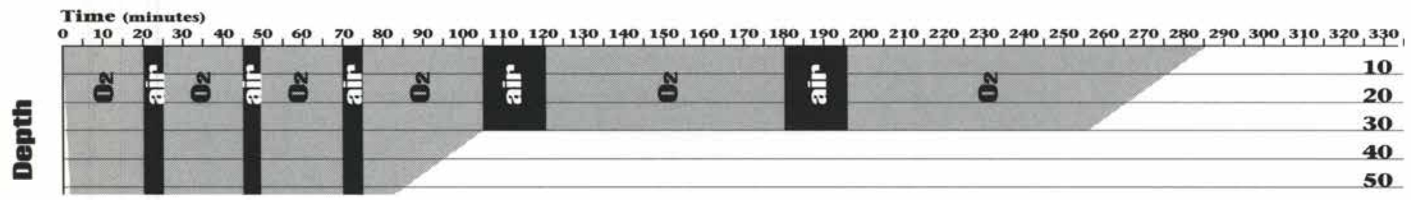
F2



USN Table 5 sometimes described as a *"carrot to lure the diver into the chamber"* is intended for pain-only DCI where symptoms completely resolve within 10 minutes at 60 fsw (2.8 atm).

USN Table 6

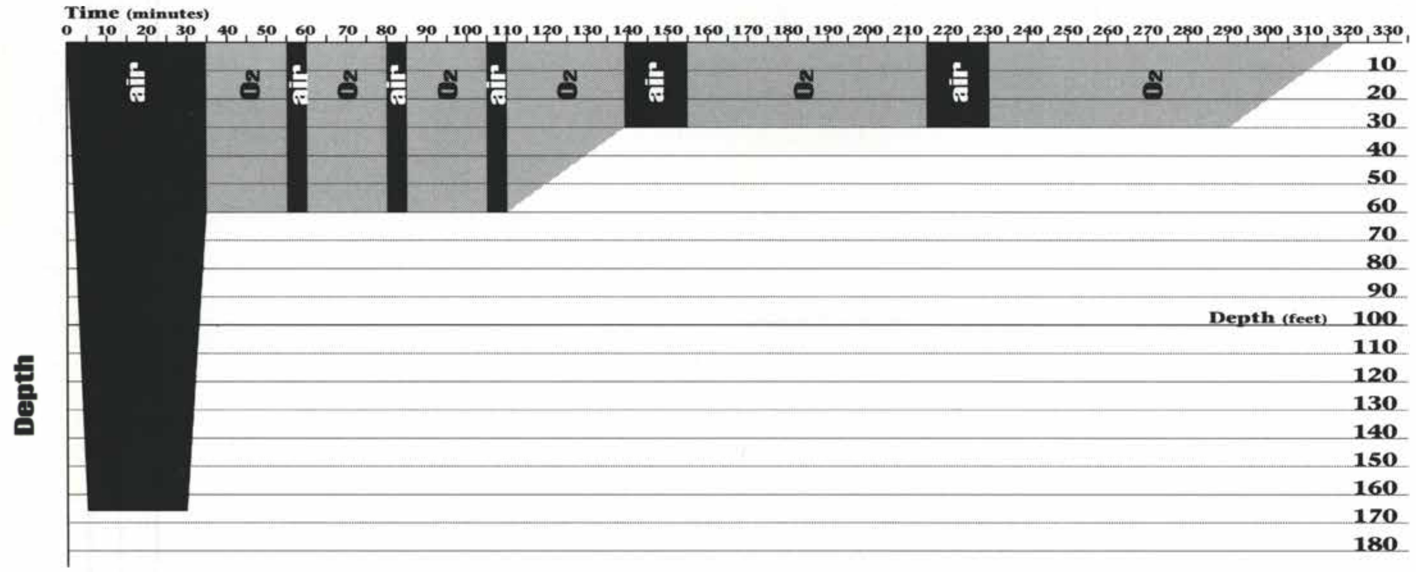
F3



USN Table 6, is becoming the primary treatment table for acute neurological DCI with a runtime of a little over six and half hours.

USN Table 6a

F4



USN 6a was originally intended for the treatment of cerebral air embolism and acute neurolgical DCI. Today, there is a question whether the benefits of the deep "air" dip to 165 fsw (6 atm) outweigh the risks of additional nitrogen loading and other operation difficulties. Some leading edge facilities are substituting enriched air, for example, an EAN 50, (50% O2, 50% N2) for air to minimize additional gas loading.

ment of pain-only DCI where symptoms completely resolve within 10 minutes at 60 fsw (18 msw); cases of omitted decompression; or as a test of pressure used to determine if atypical symptoms may be decompression illness. Many diving doctors in the U.S. today will not use a Table 5 for liability reasons related to the potential for undiagnosed neurological involvement or recurrence of symptoms, though others believe it works and should be used when appropriate. A profile of Table 5 is shown in the Figure 2 on the left.

Recompression is from the surface to 60 fsw (18 msw) at 25 fsw (8 msw) per minute, with the patient breathing oxygen throughout the descent. The patient continues to breath oxygen for 20 minutes at 60 fsw (18 msw). After the initial 20-minute oxygen breathing period, the patient breathes chamber air for five minutes followed by a second 20-minute period of oxygen breathing. The five-minute air breathing period reduces the potential for central nervous system (CNS) oxygen toxicity, usually manifested as a seizure. After the second oxygen breathing period, and if all symptoms have resolved within 10 minutes of arrival at 60 fsw (18 msw), the patient is decompressed at 1 foot per minute to 30 fsw (9 msw) while continuing to breathe oxygen. Upon arrival at 30 fsw (9 msw), the patient takes a five-minute air break, followed by a final 20-minute oxygen period at 30 fsw (9 msw). After a third five-minute air break, the patient is decompressed while breathing oxygen at 1 foot per minute to the surface. Total treatment time is 135 minutes.

Treatment Table 6 is used to treat acute neurological DCI and for all other circumstances where treatment according to Table 5 do not apply. Table 6 is similar in many respects to Table 5 but requires additional and extended oxygen breathing periods. As shown in the Figure 3, Table 6 requires three 20-minute oxygen breathing periods, called "cycles" at 60 fsw (18 msw) as compared to two required by Table 5. Additionally, two more oxygen breathing periods interspersed with breathing chamber air can be added at 60 fsw (18 msw) in the event of incomplete resolution of symptoms during the initial treatment periods. Treatment Table 6 also differs from Table 5 in that two 60-minute oxygen breathing periods are required at 30 fsw (9 msw) with 15-minute air breathing breaks between oxygen breathing periods. Again, Table 6 can be extended at 30 fsw (18 msw) to allow the insertion of two more 60-minute oxygen breathing periods if necessary. Total treatment time is 285 minutes without table extensions.

Table 6 is replacing Table 5 as the preferred table for treating all forms of DCI. The extra oxygen breathing at depth minimizes the chance of symptoms recurring after treatment for all cases successfully treated. Moreover, this table provides more flexibility in dealing with difficult or slow-to-respond cases.

Treatment Table 6A is intended for the treatment of cerebral air embolism, though there is some question as to its usefulness when there have been major delays between the time of the incident and instituting treatment, and for treating neurological decompression illness. Table 6A (Figure 4) adds a rapid compression to 165 fsw (50 msw) for 30 minutes to a Table 6. The pressurization to 165 fsw (50 msw) provides additional bubble compression in an effort to reestablish circulation quickly to occluded vessels in the brain. If symptoms resolve within 30 minutes, the patient is decompressed to 60 fsw (18 msw), where treatment according to Table 6 is begun. If in the judgment of the treating physician additional treatment at 165 fsw (50 msw) is required, the patient can be held at the higher pressure for up to two hours and decompressed on treatment Table 4.

Treatment Table 4 is a long air breathing table requiring 38 hours, 11 minutes to complete, and as mentioned above, is sometimes started in the event additional treatment is required at 165 fsw (50 msw) during a Table 6a. Rather than following this table throughout, when it is used, it is common practice to decompress to 60 fsw according to the table and then to switch to a Table 6 at 60 fsw (50 msw). Decompression can then proceed via Table 6 with all appropriate oxygen breathing extensions to the surface. In certain specially equipped facilities, enriched air ("nitrox") and heliox mixtures, designed to maintain a PO2 of 2.8 ATA (40% oxygen) are used at 165 fsw (18 msw) to reduce the amount of additional inert gas loading during treatment.

Treatment table 7 is shown in the Figure 5 below. This table is used only as a last resort, when the severity of the symptoms are such that residual impairment or loss of life may result if the currently prescribed decompression from 60 fsw is undertaken. Examples include complete paralysis of limbs, coma, and/or loss of spontaneous respiration. It should not be used for residual symptoms such as changes in sensation termed paresthesia, limb weakness where the patient can move the limb against gravity, or when loss of bladder control occurs without limb paralysis. These symptoms often respond to repeated daily hyperbaric oxygen treatments according to treatment Tables 5 or 6.

As can be seen from the figure, treatment length is at least 48 hours. Such lengthy treatment requires a special facility and adequate personnel to support such treatment. In general the treatment chamber should be a multiplace chamber with both inner and outer locks to allow personnel to enter or leave the chamber and supplies to be locked down to the divers. Because of the extensive and slow decompression required, a life support system or air supply system and an appropriate back-up are needed to support this table. Loss of air supply and the need to return to the surface will result in recurrence of bends, usually with worsening of symptoms and the development of bends in the patient's attendants.

OXYGEN TOXICITY

Oxygen toxicity may develop during treatment, particularly when the oxygen treatment tables are used. Toxicity may take two forms: 1) central nervous system toxicity and 2) pulmonary toxicity. Warning signs of CNS oxygen toxicity include tunnel vision; abnormal ringing or roaring sounds in the ears; nausea; muscle twitching, usually in the lips or face; dizziness; and change in behavior, including confusion, though these cannot be relied on; *CNS toxicity frequently occurs without warning.* If oxygen breathing is continued, a generalized seizure will occur. For the resting chamber patient, CNS oxygen toxicity is unlikely at depths of 50 fsw (15 msw while breathing pure PO2 =2.5 atm) or shallower, and extremely unlikely at depths of 30 fsw (9 msw) and shallower. If signs of CNS toxicity develop, oxygen breathing is stopped, and the patient is allowed to breathe chamber air. Oxygen administration can be restarted 15 minutes after all symptoms have resided.

Pulmonary oxygen toxicity is manifested by symptoms of chest discomfort and burning, particularly on deep inhalation. It is the result of lung irritation as a result of breathing oxygen with a partial pressure above 0.5 atm.—equivalent to breathing 50% oxygen on the surface for prolonged periods of time. Generally, the administration of a single treatment Table 6 does not cause pulmonary oxygen toxicity unless a significant amount of oxygen was breathed during the previous dive or during transport for treatment. It is rarely a major risk factor, nor does it usually require action when it does occur.

RECURRENCES

Recurrences of symptoms or worsening of incompletely resolved symptoms may occur during the decompression phases of treatment, or shortly after treatment is completed. This happens most frequently after treatment Table 5. For recurrences during treatment, the patients should be recompressed to the depth from which decompression had begun, usually 60 fsw for Tables 5 or 6. The table is then either repeated at that depth, or an alternate more conservative treatment schedule is selected (i.e., treatment Table 6 instead of Table 5, or treatment Table 6 with extensions).

ADJUNCTIVE THERAPY

Many bend patients are dehydrated from water loss due to immersion or from tissue swelling caused by the disease process. Most bends patients will benefit from hydration. Conscious individuals may take fluids by mouth, but those who are severely ill or unconscious will require intravenous therapy.

Steroids have been used often in an attempt to reduce CNS edema in severe cases of spinal cord DCI, but they do not seem to be helpful. Similarly the use of other drugs, such as aspirin, to reduce platelet adhesiveness and the tendency of blood to clot have been proposed, but none of these have been conclusively shown to be helpful. In fact most research has indicated that for most of these therapies to be useful in preventing the secondary effects of an illness, they usually must be given prior to the initiating event.

RESIDUAL SYMPTOMS

When the time from the onset of symptoms until recompression is begun is long, DCI symptoms often will not resolve completely during initial treatment. Residual symptoms may be treated by once-daily administration of treatment Table 6 or twice-daily therapy on treatment Table 5 as long as improvement is achieved. Some further resolution of symptoms may continue once treatment is terminated. However, in severe cases—especially of spinal cord involvement—complete recovery cannot be assured.

FLYING AFTER TREATMENT

Current U.S. Navy recommendations are that divers not fly for 24 hours after treatment for pain-only DCI where all symptoms were resolved; for 48 hours for neurological DCI with complete relief; and for 72 hours when Table 4 was used, or when the diver has residual symptoms from treatment.

When evacuating a patient to a treatment facility, or immediately after completing initial treatment, the individual should be flown in a plane that can be pressurized to 1 atm or as low as possible in an unpressurized aircraft.

CONCLUSION

This article describes U.S. Navy practices in the treatment of decompression illness. Although tables used by other navies and diving organizations may vary, many are similar to those described above. Also, the educated diver will realize that much of the data, upon which these procedures are based, is empirical; many of the recommendations e.g. flying after treatment, come from physicians rather than from a carefully conducted research study. As a result, the recommendations contained here may change as new information is obtained. The experienced diving physician should apply them as most appropriate for the individual case; the exact treatment given an individual diver may vary, and of course, if in doubt, should seek out appropriate expert help.

Dr. John Zumrick is an active cave diver and practicing anesthesiologist with the U.S. Navy. Prior to serving his residency at Bethesda Naval Hospital, he served as a medical officer at the Navy's Experimental Diving Unit in Panama City, Florida. He can be contacted at: 1588 Chain Ferry Way, Orange Park, FL 32073.

Using Heliox to Treat Decompression Illness

by Phillip James

The evidence that air therapy is unsatisfactory in the treatment of decompression illness after air dives, was first reviewed by the U. S. Navy (Rivera) in 1964. By this time, the Navy had become involved in the treatment of sport divers, and characteristically, there were often long delays after an incident before treatment was instituted. The failure rate for "long air tables," USN 3 and 4 was found to be 46%. This review revived interest in the use of pure oxygen in therapy proposed by Behnke and Shaw (1937) and led to the development of minimal oxygen breathing recompression tables by Goodman and Workman. The tables, designated USN 5, 5a, 6, 6a were incorporated into the first subsequent revision of the US Navy manual released in 1970 **(see previous article)**. However, experience with these procedures between 1965 and 1969 had already shown that breathing oxygen on recompression to 60 fsw (18 msw), could on occasion paradoxically be associated with worsening of symptoms, including increased pain or even the development of neurological symptoms. It could be interpreted that this indicated the need for deeper recompression and the manual called for further compression to 165 fsw (50 msw) on air followed by a USN Table 4. However, this was clearly unsatisfactory as it had already proven to be the less effective procedure. Never the less, this recommendation is still current.

Following problems in the U.K. with divers with unresolved decompression illness at 165 fsw (50 msw), marginally successful attempts were made to introduce nitrox saturation techniques. These were based on initial decompression from 165 fsw (50 msw) for two hours. The initial decompression was then to 100 fsw (30 msw) with the introduction of pure nitrogen to lower the partial pressures of oxygen to normoxic levels (PO2=0.21 atm). After a hold period, a nitrox saturation decompression was then suggested. However, in commercial diving, switching to heliox in difficult cases was proving very successful. The option of using heliox 20/80 (20% oxygen, 80% He) had been strongly recommended in US Navy manuals, dating back to 1958 for serious cases, recurrence of symptoms, and when the patient had difficulty breathing. Unfortunately, although the option has never been withdrawn by the US Navy, experiments involving gas switches in the 1970's caused concern about the procedure. These experiments rose from studies of breathing resistance in which a denser gas was breathed by saturated divers in a heliox environment (Blenkarn et al 1971). This phenomenon, later named counterdiffusion, causes supersaturation and bubble formation when a tissue loaded with a dense, slowly diffusing gas is exposed to a lighter, rapidly diffusing gas.

Subsequent evaluation of the experimental data from switching gases indicated that switching from air to heliox for therapy was in fact, safe, because of the undersaturation produced by the recompression which is performed in making the switch. However, the opposite case, that is, the recompression of serious cases involving oxygen-helium dives on compressed air beyond the pressure where pure oxygen can be breathed has been known to be fatal on at least one occasion (James 1991).

Recent experimental observations on the behavior of bubbles on decompression from air dives, has shown the advantages in bubble elimination from breathing heliox (Hyldegaard and Madsen 1989). In experiments in rats, bubbles in fat produced after an air dive always shrank when heliox 20/80 (20% O2, 80% He) was breathed. Further experiments in the same series have also shown that oxygen can behave paradoxically, and result in the transient expansion of bubbles before they begin to shrink.

The current US Navy recommendations regarding the management of divers deteriorating at 60 fsw (18 msw) while breathing oxygen are confusing. From the advice given, it is not clear if recompression should be undertaken to 165 fsw (50 msw) or that divers should simply be taken off oxygen and remain at 60 fsw (18 msw) for a minimum of 12 hours. This holding procedure and subsequent decompression has been designated USN Table 7 **(see previous article)**, and it is stated that this treatment should be reserved for life-threatening situations. It is surprisingly recommended that divers with unresolved neurological symptoms should be decompressed on Table 6 and then have daily hyperbaric oxygen therapy. This clearly indicates that therapy is being directed at oedema rather than the presence of gas.

The treatment of decompression illness, including gas embolism arising from pulmonary barotrauma must be based upon a proper understanding of the pathogenesis of the diseases. Although initially, events are dominated by the physical effects of bubbles, these initiate a cascade of growing complexity as alterations in vascular permeability and the release of vasoactive substances soon complicate events. The clinical and experimental data now available from research in the U.K. and elsewhere suggests that recompression to 100 fsw (30 msw) breathing heliox 50/50 is an optimum therapy for the treatment of decompression illness in both air and heliox diving, for difficult cases or when oxygen treatment at 2.8 atm is not effective. It is now standard practice in many commercial diving companies to use the 7.5 hr "Cx-30" table (Comex, 1986) for serious cases of decompression illness.

Dr. Phillip B. James is a senior lecturer in Occupational Medicine at the University of Dundee, Scotland, and serves as a consultant in hyperbaric medicine to companies such as Stolt Comex Seaway Ltd., Ocean Technical Services Ltd. Elf Aquitaine Diving Ltd and others.

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More information...

Behnke AR, Shaw LA. The use of oxygen in the treatment of compressed air illness. Nav Med Bull 1937; 35:61-73

Comex 1986. Comex Medical Book, Revised edition 1986. Marseille: Comex Services.

Goodman MW, Workman RD. Minimal recompression oxygen breathing approach to the treatment of decompression sickness in divers and aviators. Research report, 5-65. US Navy Experimental Diving Unit. Washington.

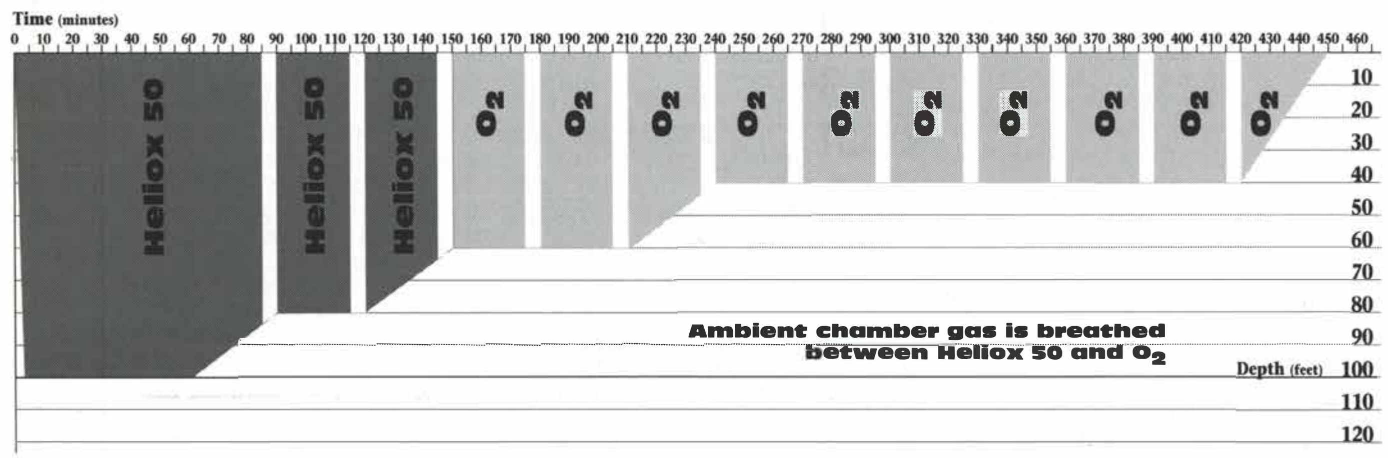
Miller JN, Fragreus L, Bennett PB, et al. Nitrogen oxygen saturation in serious cases of compressed-air illness. Lancet 1978;ii:169-71.

Blenkarn GD, Aquadro C, Hills BA, et al. Urticaria following sequential breathing of various inert gases at 7 ATA: a possible manifestation of gas-induced osmosis.Aerospace Med 1971;42:141-46

James PB. Problem areas in the therapy of neurological decompression sickness. In: Proc VII Annual Congress of the european Undersea Biomedical Society. Norwich Union press 1981;127-42.

Hyldegaard O., Madsen J. 1989 May. Influence of heliox, oxygen, and N2O-O2 breathing on N2 bubbles in adipose tissue. Undersea Biomed Res 16(3): 185-94.

CX-30 Table(Comex, 1986) F5



The Comex 30 Table, which uses heliox 50 (50% O2, 50% He), is intended to treat acute neurological decompression illness following a normal decompression after an air, enriched air or helium mix dive.

Treating "Mix" Bends

Over the past year, there has been considerable confusion and misinformation, regarding the treatment of decompression illness resulting from non-air "mix" dives. We offer the following medical opinions to address this unfortunate situation.

Photo by: John Comly

RE: **Treating Enriched Air ("nitrox") Divers**
FR: **Dr. R.W. Hamilton**

Oct92. "This fall the Cayman Islands Watersports Association published a report with some dangerously incorrect information. As a physiologist, I want to try to correct the Cayman Islands misconception about treatment before somebody gets hurt."

"The dangerous misconception is that a diver who may incur decompression illness as a result of a dive using enriched air (called "nitrox" by some) cannot be treated using standard oxygen-recompression procedures such as the USN Table 6. This is wrong. The treatment will work just as well following an enriched air dive (or a "trimix" or heliox dive for that matter) as for an air dive. It is the method of choice. I submit that no qualified diving doctor would disagree with this point."

"For the record, it appears that the issue revolves around the extra oxygen exposure resulting from enriched air diving, and the potential for "whole body" (or lung) oxygen toxicity should treatment be needed. For the "recreational" exposure to enriched air, the extra oxygen dose is trivial; its effects would be entirely obscured by the large variation in sensitivity among individuals."

"For the unlikely combination of a larger "commercial" type of exposure, and an unusually difficult treatment, the doctor might have to take lung toxicity into account during the treatment, but such management of oxygen exposure is a normal part of hyperbaric oxygen therapy."

R.W. Hamilton

TO: **Dr. Steve Lombardo, Staten Island, NY**
RE: **Treating Trimix Divers**
FR: **Dr. C.J. Lambertsen, University of Pennsylvania Medical Center**

Jan92. "I have your note of 19 December 91 concerning bends in trimix diving. The best I can do for you is to say that there is no useful information of the type and amount that would allow distinctions among character and therapy required for treating air, nitrox, heliox or trimix. Moreover, it is physically and physiologically not conceivable that mechanisms of bubble formation or effects of gas bubbles would differ. The differences would be in details of prevention, using appropriate models of gas exchange and bubble dynamics."

TO: **Capt. Thalmann**
FR: **Surg. Capt. Pearson, Royal Navy**
RE: **Trimix Diving**

Aug92. The Royal Navy carried out several hundred man-dives on what we called "trimix" in the late 70's early 80's. I realize that the word "trimix" has been applied to a variety of breathing mixtures but in our case it was either a trimix 20/40 or 18/41 (O2%, He %, bal. N2). Our intention was to produce a gas mix for surface supplied mine countermeasures diving in the 54-80 msw (180-265 fsw) range which could be used from small inflatable craft. Trimix was chosen to avoid the need to use a speech unscrambler, reduce nitrogen narcosis and to cut down on the respiratory heat loss associated with heliox which, in the case of divers using passive thermal protection, would probably have been quite limiting, bearing in mind we were looking for 25 minute bottomtimes at 80 msw (265 fsw) followed by in-water decompression of about 75 minutes (*Note that there is some debate as to whether breathing open circuit helium mixes on short bounce dives in the 200-500 fsw (60-150 msw) range creates thermal problems compared to the well known problems of using helium mixes as suit inflation gases. See,* "The Case For Heliox," *by Dr. Bill Stone,* aquaCorps Journal *n4, "MIX."1992—ed.).*

Initially, a lot of dives were carried out at the Deep Trials Unit (DTU) using the trimix 20/40 to establish the maximum upward pull which could be carried out after 25 min. at 80 msw (Bottom mix PO2=1.8 atm). This rather strange experiment was aimed at providing basic information for a mathematical model. From there, a number of wet dives were carried out which suggested that a PO2 of 1.8 bar at 80 msw was too much and a decision was made to go to a trimix 18/41 (PO2=1.62 atm. *Note full face masks and helmets were used—ed.*). The tables being developed relied on a switch to pure 02 at 15 msw (50 fsw)—later cut back to 12 and then 9 msw (40 and30 fsw). We eventually ended up with decompression times that were shorter than heliox tables but a little longer than the deep (beyond 50 msw or 165 fsw) air/oxygen tables which were then in the Royal Navy Diving Manual.

After the wet dives at DTU, three of four periods of sea-trials took place in the Clyde area. I should add that all dives were carried out in accordance with comprehensive protocols and the sea-trials required a heliox compatible chamber at the surface to allow immediate treatment. Our treatment protocol did allow the use of heliox for 'blow-ups' and refractory DCI.

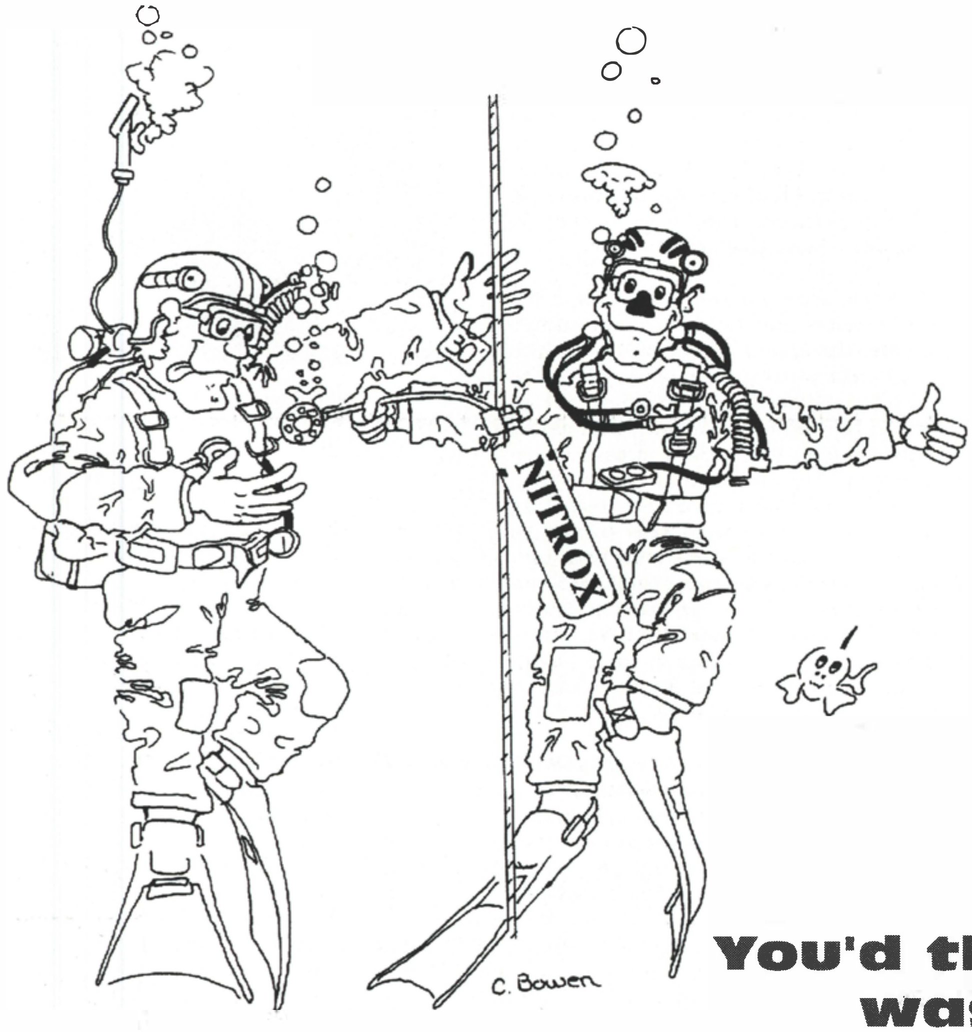
As far as I remember, we had about 15 cases of DCS all but one of which were "joint pain only." The majority of these came from the early trials at DTU and were all treated with RN TT62. (USN Navy Treatment Table 6) with recompression to 18 msw (60 fsw) on 02. I do not remember any unusual problems with these cases and there was nothing unusual in their presentation. The early trials did result in one case of cerebral arterial gas embolism although this was a retrospective diagnosis and it was originally thought to be case of neurological DCI. It was also treated on the equivalent of a USN TT6. Again, the response to recompression was rapid and full.

The sea trials resulted in about five "pain only" bends and a possible neurological bend. All occurred some hours after decompression but were treated quickly and had a uniformly good response to recompression. Once again, the RN equivalent of USN TT6 was used. *The main problem revealed by the trials was 02 toxicity occurring during the in water stops despite switching at shallower depths and making a fairly gradual transition to 02 breathing.* This led us to wonder whether trimix had any predisposing effect, but I suspect part of the problem was too much dead space in the helmets *(possible CO2 build-up—ed.)* due to poorly fitted liners.

(Note that in light of recent thinking, see, "Rethinking Oxygen Limits," *by Dr. R.W. Bill Hamilton,* technicalDIVER *3.2, Fall92, this experience supports the contention that a working PO2 of 1.6 atm for 25 min., in a possible high CO2 environment, followed by in-water O2 at 9 msw (PO2= 1.9 atm) is excessive, read high risk, from a CNS toxicity clock perspective. The thinking today is to run the working phase of the dive at a PO2 less than 1.5 atm.—ed.)*

In conclusion, *we did not uncover any problems as far as the presentation and treatment of DCI was concerned (italic—ed.)* and this is, as far as I know, the experience of the French Navy who dived a similar mix for a few years. I would add that this is not a mix to be used by sport divers for a number of reasons and, as I mentioned earlier on, it does not have any particular advantages in the less than 50 msw (165 fsw) range.

Special thanks to Drs. Hamilton, Lambertson and Capts. Pearson and Thalmann for allowing us to reprint these materials.



You'd think oxygen was a drug

Making the Grade

Interview With Lad Handelman
by Michael Menduno

Growing up in Mt. Vernon, New York, under the shadow of Yankee Stadium, 16 year old Lad Handelman left a questionable future in the Bronx to move west and become a California abalone diver under the tutelage of his "Uncle Jimmy." In five short years, as a hard working diver, Handelman made the ranks of California's "Black Fleet" abalone divers, and in 1962, was invited to join General Offshore Divers, the first helium diving company in the U.S., organized by visionary Dan Wilson. Having pioneered commercial "oxy-helium" (heliox) diving techniques, the company was acquired by Union Carbide two years later, and renamed Ocean Systems.

In 1965, chafing under the thumb of a corporate parent, Handelman and a few of his abalone partners left to form Cal-Dive, at a time when "oilfield" diving was a glamour industry and some of America's premiere corporations had moved in for a piece of the action.*Why would a multinational oil company hire an upstart group of former abalone divers over the likes of Westinghouse, International Utilities or Brown and Root?* As one of the principal divers, and Cal-Dive's sole salesman, Handelman, and his partners asked that question a lot that first long year until Humble Oil gave them their shot. After that, they never missed a lick.

Offshore diving was becoming an expensive proposition in the "go-go" late sixties as bell diving and saturation techniques became the order of the day. Strapped to build bells, with annual sales mounting U.S.$600,000, and the heady lure of three corporate buyout offers on the table, cash-hungry Cal-Dive, took a leap of faith—or perhaps it was just plain tenacity—and on the advice of Can-Dive partner, Phil Nuytten, told its suitors to *"go fly a kite."*

Within sixty days, Cal-Dive changed it's name to "Oceaneering International," and with the help of Mat Simonds of Simonds Associates, now a leading oil-field financial services group, raised U.S. $350 thousand. With Handelman as its CEO, Oceaneering, soon joined by Mike Hughes and Worldwide Divers, eventually went public, growing to U.S.$52 million in 1975, operating worldwide in over 24 countries. More challenges.

In 1978, after a severe downturn in the oil industry and fall in Oceaneering's profits, Handelman had a falling out with his Board of Directors who wanted to cash out the company. Though he lost his battle; he won the war and Oceaneering International, the world's largest diving company, has remained an independent to this day. However, in the resulting shoot-out, Handelman was forced to leave the company. Others left voluntarily. Less than a year later, Handelman and several of his ex-Oceaneering diving executives, resurrected Cal-Dive, building it to U.S. $16 million in sales before selling it to Diversified Energies Inc. in 1983 on an "earn out" basis.

Two years later, Handelman, broke his neck in a skiing accident. Confined to a wheelchair since, Handelman, father of three, has been a prime mover in a number of diving business and charitable ventures from his base in Santa Barbara, California. M2


Photograph by ADC's *Underwater*

Lad Handelman at home in Santa Barbara, California with his three children, Jim, Laurie and Roy.

c: You got your start in abalone diving back in the early sixties when you were only 16 years old. It must have been hard work?

LH: The top divers in those days could pick their day's catch in about maybe five, six hours in the water. A good boat might pick a hundred dozen a a day. That was the limit.

My first set-up was a 16 foot skiff with a 10 horsepower outboard motor, a garden hose, a bronze Widoff mask, a rubber suit, boots with iron plates bolted on to galoshes, and about a two-pound machete to cut the kelp and pry off abalone. As a beginning diver, I would spend 8 to 10 hours under water, and probably would pick anywhere from 15-20 dozen. It wasn't that easy for me to figure out what it was all about, but that's where just plain hours in the water pays off.

a/c: How long did you work as a diver?

LH: I spent about five years as an abalone diver and eventually made the grade in the major leagues, so to speak, and became a member of the Black Fleet. The Black Fleet was the premier group of divers in California in those days, the scourge of the industry. Interestingly, the most successful commercial abalone divers were eventually to make up the ranks of most of the large major offshore diving contractors in years to come—people like Danny Wilson, Murray Black, Whitey Stefens, Jerry Todd, Bob Kirby, Bev Morgan—to name a few.

a/c: Offshore was pretty competitive.

LH: Yeah. It sorted out the real serious competitive divers from the would-be divers.

a/c: How did you get started offshore?

LH: Because of the reputation I had made for myself as a hard-working abalone diver Danny Wilson asked me to join him in the first helium diving company, along with Whitey Stefens. The company was named General Offshore Divers. Even though I had no mechanical knowledge or experience at all in the oil patch, he reckoned anybody that could pick more abalone than him couldn't be all bad. He had thought he was the greatest.

Dan had the vision and imagination to connect the use of oxy-helium (heliox) to making money in the oil patch. He was the very first one who seized on the idea.

a/c: What was the motivation to start working with helium mixes?

LH: Two things. First of all, a company called Associated Divers, the "King Kongs" of oil field diving were getting 100% of all the deep-water work. Nobody else could get in the business. They had a monopoly and were capable of diving air to 250 fsw (75 msw). They were all incredibly competitive and efficient divers and could handle air at those depths.

In those days, no one was taking newcomers. So to be able to leave the abalone industry and progress career and achievement-wise, and be competitive again with the group I admired, using a new fangled idea, seemed pretty special. No one else was offering oxy-helium, in fact, Associated prided themselves on diving on air, but the oil companies' goals couldn't be met.

a/c: For deeper work?

LH: There was work at deeper depths and a need for more effective work at depths in the range of 180 fsw (54 msw) and beyond. The top guys were pretty limited on air. They could only put in about 22 minutes bottom time at 250 fsw (76 msw), and even though they got the work done, it took a lot of dives to do a job. In comparison, in a one hour of oxy-helium dive, (an hour bottom time) we probably achieved more work than three other divers. Far more. Not only did we have three times the bottom time, but we could work doubly hard from a ventilation perspective without the adverse effects of narcosis and CO2 level build-up. We didn't need to be better divers; we had the helium advantage.

a/c: Were you using standard breathing equipment?

LH: One of Danny's key inventions was to put a demand regulator system inside the hardhat. It was the first of its kind. That's what he brought to the table. It was the only way to afford the gas. Without a demand regulator, it would have taken four to five times as much gas to do a dive, which would have meant we'd use up a whole ship load to get a job done.

a/c: What about tables?

LH: The only information available at the time was the U.S. Navy Diving Manual. We learned straightaway that the U.S. Navy Tables weren't sufficient for commercial work; we had a lot of worries about the in-water oxygen and got various levels of bends after every dive.

a/c: Ouch. Were you operating with a chamber?

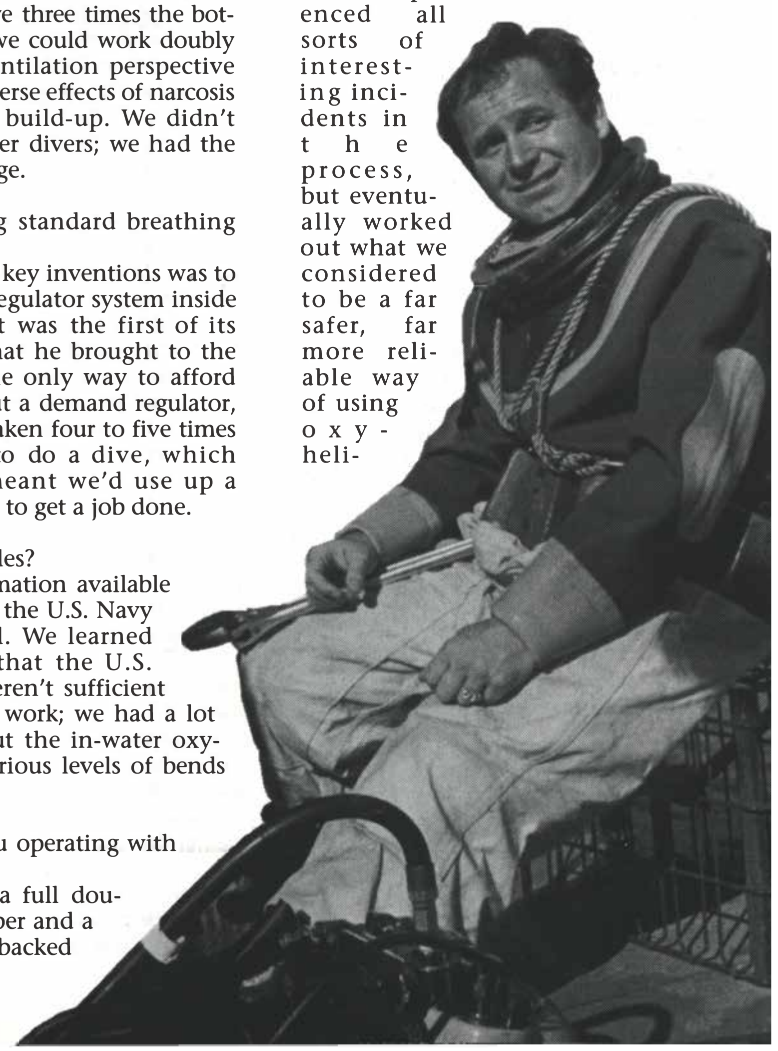
LH: Yeah. We had a full double-place chamber and a five-man crew backed by standby divers and so forth. I'd say we got bent two dives out of three.

The top guys were pretty limited on air. They could only put in about 22 minutes bottom time at 250 fsw (75 msw), and even though they got the work done, it took a lot of dives to get the job done.

a/c: So how did you actually work out your tables?

LH: I'm a little ashamed to have to explain that for this particular article, because the point I wanted to make is to be conservative, and warn people what not to do. So having said that, it's hard to talk out of the other side of my mouth and say, we made ourselves guinea pigs.

We had a chamber hooked up in our dive shop and whenever we had the chance in between jobs, we tried different ideas, different mixes—the whole works—in the shop chamber. Then we'd go on the job and try it. We experienced all sorts of interesting incidents in the process, but eventually worked out what we considered to be a far safer, far more reliable way of using oxy-heli-



um than the Navy Tables. We never could have made it with the Navy Tables and procedures.

a/c: In those days, you couldn't just ring up a "decompression guru" and have them cut you a set of tables?

LH: Exactly. But keep in mind, we weren't a bunch of wild-ass divers doing this just for the hell of it. We were very serious about our work and very concerned about our safety. We felt the approach we took was as safe as possible under the circumstances. There were a lot of operational issues to deal with.

a/c: Like what?

LH: Cold for one. And oxygen. The problem was that with water temperatures in the low to mid 50's (10-12° C), we were cold after an hour's bottom time and we still had another two-and-half-hours to spend in the water *(Note that the early hardhat systems did not utilize a neck dam, consequently the breathing gas, in this case heliox, was pumped directly into the suit, creating significant thermal chilling—ed.)*. Originally, we would stay on gas until 40 fsw (12 msw) as called for on the USN tables and then go on oxygen. By that time you were frozen to death, your mouth was numb on the regulator and you had to worry if you were going to get oxygen poisoning or blow yourself up. The challenge was to work out an appropriate set of procedures; gas switches, decompression, and thermal wear that would work.

After the first half year of freezing in the water, we learned to switch to air at our first or second decompression stop; then we could go on full ventilation, get off the regulator, lean back and relax and thaw out. It was like taking a hot-tub after being on oxy-helium. It was very comfortable—that different. Eventually, we eliminated oxygen in the water altogether for fear of grease in the hoses, and contamination from oil-pumped air. We happily lengthened our decompression tables so that we could stay on air the entire time. Later on, we refined our procedures to be able to use nitrox mixes (enriched air "nitrox") as intermediate gases. Understand that this was still in the early days before bell diving and deck decompression became standard practice. Eventually the industry moved to saturation diving for deep work but it takes a massive amount of equipment—*50 tons on deck* —to make one saturation dive.

a/c: It sounds like it was a 'risky business' in those days.

But the reason we originally took the risks we did was because there was no other choice. There was no book to go to, no expert to go to to provide us with a way to get the work done, other than what we did.

LH: It was. But the reason we originally took the risks we did was because there was no other choice. There was no book to go to other than the Navy manual, and no expert to go to provide us with a way to get the work done other than our own trial and error. Of course, having said and done that, you should understand it was not a continuing policy. A commercial diving company can't have that kind of policy if it is going to offer the people that come along a safe place to work. And that goes for the type of equipment, type of procedures, type of work they take on—the whole works. Insurance becomes the major concern if you want to stay in business. You have to have insurance. That drives companies.

a/c: You must have faced a real insurance problem when you started diving helium? Would anyone insure you? How about liability issues?

LH: In the very early days, we worked as self-contractors. We all were partners in the company, and we didn't have the insurance coverage that would be standard today. We were not only pioneering diving techniques, we were pioneering how to be in the diving business. Nowadays that wouldn't fly. In those days there wasn't anything else around. Companies like ours were "the only girl in town" and the oil companies had to live with whatever they got. Eventually, our company, General Offshore Divers, was able to virtually knock Associated Divers out of the box.

Later, when we started Cal-Dive in 1965, it was the same thing. The principals in the company were the divers and as principals we didn't have to be covered by "company insurance". We took our own risks and were exposed individually. Eventually we built up a sufficient

We were not only pioneering diving techniques, we were pioneering how to be in the diving business. Nowadays that wouldn't fly.

record to where we could obtain insurance. Then, once we got to be a little larger company and the work had to be undertaken by non-principals, we had to obtain insurance to cover those people. Of course by then, the conglomerates were in the picture with unlimited resources and insurance and Cal-Dive was at a real disadvantage.

a/c: Let's talk about the differences between commercial and sport diving. What is commercial diving all about?

LH: I'll define my sense of commercial diving. You're down there to do a job for pay. You involve other individuals with your project including company support-divers and crews. You work for a client whose got plant and equipment, whether it be an oil platform or a dam. He's got his assets at stake. You don't have the liberty or freedom to exercise much in the way of personal desire or personal risk-taking for the sake of your own sense of achievement because you're responsible for too many things aside from your own individual desires and purposes. You're part of an overall commercial picture. One mishap on your part can bring the farm down. They're not paying you to do that; they're not paying you to go out there and be a hero, take any chances, or try to prove anything. They simply want a job done in the most risk-free, efficient way possible. That's what it's about. If you don't like that, then you shouldn't get involved in the business.

a/c: What about the divers themselves? What motivates a commercial diver?

LH: Very often people become a commercial diver because they simply don't fit in the regular working world. They don't aspire to be involved in corporations or organizations; they don't want to conform. They like the idea of working in a capacity where they can be more individualistic, like the commercial abalone or sea urchin diver whose got his own boat. To some extent, the top oil field and construction divers share that. Their reputation lets them call their own shots to a large degree.

a/c: What about love? Is it the love of diving? Is there something about the environment that draws them, or is it just a job that pays good money?

LH: I don't think it's love of diving per say. It's the love of not being strapped to a nine-to-five office job. It's a love for independence. Challenge. A freelance diver is a very independent animal. If he's really good, he can find work around the world, make a lot of money in a short time and then do what he wants. It's a lifestyle that appeals to that kind of individual. You see exotic places, meet exotic women, you have more than your share of fun and adventure.

a/c: Are there many women involved in commercial diving?

LH: No, not on the jobs. But you find yourself in places like the North Sea or working out of Singapore or Thailand and you make your time count when you're on the beach. That's the type of lifestyle that attracts young fellas to want to be in commercial diving. Of course, the top divers also have an opportunity to get their own companies going or become a partner in a company.

a/c: In the sixties, mix and saturation techniques represented the leading edge of commercial diving, what are the "hot" areas of development today?

LH: With the development of saturation diving, I think it's been fairly well sorted out as to how to best go about achieving work at depths to 600, even to a 1000 fsw (184-306 msw) *(Note that 350 msw working dives represent the deepest commercial working dives being conducted today—ed.)*. We've thrashed out most of the procedures and have evolved a system that's insurable, acceptable to our clients, and consistently works as far as our divers and people go. There's not a lot that can be gained for a company to try to revolutionize it. Of course, there's going to be refinements made, but I don't see any revolution on the horizon at these depths. Even if the potential was there, most companies

Successful companies analyze a job and the inherent risk of it and then find a way to break that job up into safe pieces. With the right equipment and qualified individuals and procedures, the work can be done successfully.

would do better expending their energies, not in revolutionizing, but in doing a better job and reducing costs. The "hot" area , if you will, is the continuing development of unmanned diving systems like remotely controlled vehicles (ROV), one atmosphere suits, and other engineering approaches to accomplishing the work.

a/c: Will machines eventually replace divers for deep work and other tasks?

LH: As time goes on, it seems that machines keep improving in their ability to perform the work more reliably even if not as quickly, even if not as extensively. In the future it's likely that more and more work will be done by machines because no one wants to see an individuals' health and safety risked. In fact, it's happening now.

I'm not saying that for the most part, good scuba divers can't do jobs safely. But the inherent nature of scuba invites problems, incidents where the chain of events gets out of control and result in a fatality. The ingredients of a limited gas supply, no communications and no tether on a complex job site are like mixing nitro and glycerin.

a/c: You've mentioned the word "safe" a number of times. What is "safe" in commercial diving? Obviously being down at 600 fsw (184 msw) or working with heavy equipment is a "high-risk job." What is acceptable risk in commercial diving?

LH: That's impossible to define. I could say that beginning in 1965, Cal-Dive went five years straight without a single fatality or injury, and we had an outstanding record at Oceaneering as well. We tackled many, many types of jobs and many types of extreme conditions. So I think you can say that it's possible even in a very hazardous industry to adopt a very conservative approach. That comes from turning down certain kinds of work or refusing to work under certain conditions, not being bullied by the customer into doing things to where your risk level is beyond your reasonable control. Successful companies analyze a job and the inherent risk of it and then find a way to break that job up into safe pieces. With the right equipment and qualified individuals and procedures, the work is done successfully.

If the work appears to require things beyond the reasonable control of the diving crew, then it's the duty of the diving superintendent to refuse to do that job. A diving company's policy, set by the CEO, the executives and the board of directors, is to recruit qualified superintendents and provide them with guidelines that dictate in broad terms how they should handle onsite operational decisions. It's his job to reject any work, if need be, before risk levels get out of control and that means never exposing a diver to unreasonable risk.

a/c: Safety is becoming the primary concern in the technical diving community. What are your feelings about safety in self-contained diving?

LH: I guess I'd go back to your earlier question; what's the difference between sport divers and commercial divers? I'd say a very fundamental difference is one that most sport divers would take exception to. Years ago, as Oceaneering's CEO and President, I issued a mandate outlawing scuba diving. We simply wouldn't do any scuba diving anywhere under any circumstances.

a/c: Why was that?

LH: Our experience was that we had fatalities and injuries when scuba was used, even under seemingly good conditions, compared to the thousands of hours on hose with no incidents. As CEO, I simply couldn't justify even one fatality that could have been avoided.

The turning point for us was when we acquired Divcon and had several scuba fatalities in a single twelve month period. Like most of the companies in those days, Divcon used scuba gear for a lot of their shallow projects and organized their jobs around it. In each case, the investigation revealed that if surface supply had been used we wouldn't have had a problem.

I'm not saying that for the most part, good scuba divers can't do jobs safely. But the inherent nature of scuba invites problems, incidents where the chain of events gets out of control and result in a fatality. The ingredients of a limited gas supply, no communications and no tether on a complex job site are like mixing nitro and glycerin.

I remember one incident, we had a diver in 10 fsw (3 msw) of water who got hung up on a fish net during a pipeline job. Some fishermen had left a net and top-side didn't know about it. The result was he ran out of air and drowned.

a/c: No communications to be able to say, "I'm in trouble here; I'm tangled".

LH: It was a major event. It happened in the Escravos River out of Warri, Nigeria. I personally went up there and investigated the incident. It took two-and-a-half days. Later I had to explain all this to his family. That was painful. Similar incidents happened a number of times.

After a few of those investigations, and having the job of explaining what happened to the families, and having to attend funerals, has a personal impact. You get more hardnosed and say, *"No more scuba. Period"*. The benefits of using scuba on the rare job when it could be used safely were outweighed by its inherent risks and our inability to exercise control as to when it would be used. So we pulled it.

a/c: Today as you know, technical divers are greatly expanding their diving ranges using mix and other technologies. What would you say the major risks are?

LH: Of course the obvious risk is running out of gas before you can get up. Or finding yourself in a situation where you don't have enough supply to take your proper decompression before you have to surface. So the risks range from bends, being paralyzed, to drowning, being killed— all of the above. Those are just the obvious basic risks. And I guess when I think about that, I ask, *"what is justification for taking such risks?"* That's number one. Number two is, *"what is being done to mitigate these risks?"* And number three, if one finds a way to justify and mitigate those risks, you have to ask, *"how well can you go about it, without in good conscience, knowing that you might influence someone else coming along right behind you, who doesn't have the same appreciation you do for the whole situation, who will attempt the same dive and get killed."* That's where I see the problem coming in. Not that there aren't exceptional individuals who understand all this, prepare themselves accordingly, and can do it in a manner equal to any professional commercial diver. I gotta believe there are many individuals who are easily up to that challenge. My concern is not the exceptional individuals, but others around them, who see that and automatically think, *"Well if he can do it, I can do it, too."* And then go out on their own, try to duplicate it and get killed.

Maybe special dive clubs can be formed to undertake these kinds of dives, and maybe these clubs will develop and self-impose their own set of policies and procedures, and share them with others.

a/c: Some time ago, I had an opportunity to speak to Dr. Carolyn Fife, who had run a major scientific archeology diving project in Turkey. Her group had logged about 10,000 air dives in the 160-180 fsw (49-55 msw) range, with 20-25 minute bottom times using O2 decompression. When I asked her about the project she told me, *"Sport divers shouldn't do these kind of dives."* And I said, *"Why not? Your people do."* *"That's different,"* she said, *"We're doing it for science."*

At one point when we were talking today, you said, *"That's different because it's their job."* What about the dedicated technical diver, who's not doing it for "science," or "money," but rather for their own personal reasons; the joy, the experience, the challenge, love. Does that make it any less valid in your eyes?

LH: I think that an individual has a whole different opportunity because he is involving only himself. He's not part of a large commercial structure. If he chooses to take certain risks or get killed in the process, that's his individual choice. If that same person were put in the job of being responsible for the lives of many divers, I'm sure he would look at things differently. As an individual, I might elect to do things very differently than I might as part of a commercial organization. It's not whether it's right or wrong, it's what's surrounding the choices.

I think there's probably ways you could apply the conservative and overly prudent commercial attitude to scientific or sport diving, and end up with a compromise. It may be more time-consuming; you may have to have more reserve supplies of extra bottles staged along the way, for example in cave or wreck diving. Maybe you'd have standby divers. Maybe the first part of the mission would be to stockpile reserve supplies along the divers' planned routes. I'm not sure exactly what should be done, but you probably wouldn't just venture out without having pre-thought all the consequences and taken as many steps as you could to avoid unreasonable risks.

a/c: Do you think sport and commercial divers could learn from each other?

LH: I think it's a shame that there isn't more appreciation of each other's skills and attitudes. For example, I'm enamored and in awe of the dive clubs like the Neptune Dive Club here in Southern California, and individuals like my friend, Locky Brown, a free diver who can go down without any air at all, holding his

A diver's life depends on his ability to react quickly to very frequent emergency situations that come up. That's your long suit, your ability to react and recover. When you can't do that, you get killed.

breath, and do many things that a fully-suited commercial diver would have to struggle with. I don't know if that's considered sport diving, but it's an extreme test of personal conviction, perseverance, experience and willingness to go into the environment in a pretty naked way and get some things done. Their level of expertise and capability in that world is equal to or surpasses the level of expertise that commercial people achieve, but in a different sense. Having been out there with those groups I found myself feeling totally inadequate. A big-time commercial dive man couldn't hold a candle to those guys.

a/c: There is always the problem that some people will try to do things that really aren't safe by virtue of their training or experience or the technology that they are using. How do we address that issue as a community? What do you think the answer is?

LH: I think there are some major forces at work here that just can't be managed very well at all. The biggest one, as you said, is the nature of the beast. You're not going to get individuals who do have the ability, to hold back because of the possible effect on those around them who can't. They're going to do it, period. There's no stopping that. And others will try to duplicate or follow and they may be hurt. They may not have the experience and wherewithal to realize how many steps are involved in making an otherwise pretty high-risk deal safe. So you're going to have accidents.

At some point if there are enough accidents, what will probably happen is that some regulatory body will attempt to get involved. But there are alternatives. Maybe through trial and error, the individuals involved will agree to a self-imposed type of regulation. Maybe special dive clubs can be formed to undertake these kinds of dives, and maybe these clubs will develop and self-impose their own set of policies and procedures, and share them with others. Responsible people will want to have that benefit. At least that's what I hope what would happen.

a/c: How about input from the commercial community?

LH: Who knows. Maybe some of these clubs will invite commercial people to share information and advise them, and out of that will come a compromise or solutions on how to improve the safety on some of these dives, that might not be available otherwise. Not necessarily using commercial methods, but at least a balanced approach. Maybe in that process, the macho conservative commercial people will gain a better appreciation of sport divers and realize that they are formidable individuals as well. There might even be some cross-learning. I'd be surprised if that wouldn't evolve.

a/c: As a closing question let me ask you, what advice would you offer technical divers who are involved in pioneering this new class of diving?

LH: Looking at my own situation here, after I broke my neck, I went out in the kelp beds using my old abalone gear. It felt good to do it, to be able to hit the end of my hose, and make it back in one piece. At first glance, that sounded great. I mean, here I was out of the hospital, back in my old environment, boy was it great. Pretty hot. I want to do more of that, right? Wrong.

My advice is for each individual who wants to do these dives to visualize a scenario where their own interest results in them getting wiped out. In my case, because I can't use my fingers at all, and can't grab a knife or open up a weight belt very quickly—who am I kidding? There will be a time when I get out there and get my hose tangled without the main resource I've always had— the ability to recover. A diver's life depends on his ability to react quickly to very frequent emergency situations that come up. That's your long suit, your ability to react and recover. When you can't do that, you get killed.

When you think through that scenario, a scenario that results in you getting killed.... in my own case, I thought about one of my sons up there trying to help me, or my good friends on board the boat, and how they would feel when they dragged me in, and had to live with what occurred. I'd be OK 'cause I'd be out of it then, but they would have to live with it. Going through that kind of thinking process caused me to decide to live with not doing it. I'm not going to dive a hose anymore as much as it is a part of me.

a/c: Hard decision.

LH: Ironically, I've decided to learn to scuba dive. It's kind of a reverse process. Instead of that hose being my greatest friend, when you can't get free of it, it can become your worst enemy. I'll probably be able to do just fine on limited scuba dives, free from any wrecks or entanglements, and enjoy it. A complete reversal. Ironic isn't it? It's ironic.

a/c: Yeah.

LH: I think if each person who entertains going down to a certain level of risk sees a scenario where he or she doesn't make it back, and then be forced to ask what led up to it, why did it happen, and what will be the effect on those who love and depend on them, they'll probably modify their own risk profile a lot. And it's their responsibility to do that; to assume the worst case, analyze it and then adjust their adventure accordingly. If they do that, they'll probably be OK. If they don't, then they're irresponsibly selfish in my book.

I think if each person who entertains going down to a certain level of risk sees a scenario where he or she doesn't make it back, and then be forced to ask what led up to it, why did it happen, and what will be the effect on those who love and depend on them, they'll probably modify their own risk profile a lot.

a/c: Are you aware of the organization called the Association for Handicapped Scuba (HSA) that was formed a number of years ago to teach and promote scuba diving for people with disabilities. They're quite active.

LH: They're in Newport Beach I think. One of their leading members is a woman named Julie Mora.

a/c: You know her. Good.

LH: I'm trying to make it in her community but she's way ahead of me in all respects. She's a gal who does wheelchair racing, rugby, sets records in swimming. And now scuba diving. I don't know if she's even aware of any of the things I've done in commercial diving and I don't want to tell her about it. I never talk about those things. With this crowd, you have to make it on your own.

In-Water Oxygen Recompression: A Potential Field Treatment Option For Technical Divers

by Carl Edmonds

The failure of decompression illness to respond to recompression chamber therapy is often related directly to the delay in treatment (see *"Get Me To The Chamber On Time,"* staff. *aquaCorps Journal* N1, 1990). Sometimes chambers are simply not readily available. For these reasons, immediate in-water air recompression has been used in Hawaii, with good results, and also among the professional shell divers of Australia, at least until the underwater oxygen became available: Interesting enough, most diving medical text books do not even mention in-water therapy as an option.

When using in-water air recompression therapy, pressure is exerted by water instead of in a recompression chamber, while air is usually supplied from compressors sited on the diving boat. Although this treatment is frequently ridiculed by those in the cloistered academic environments, especially those committed to elaborate recompression facilities, it has frequently been the only therapy available to severely injured divers, has had many successes, and is recognized by many experienced and practical divers to often be of life saving value. This has certainly been the case in remote localities such as the pearl fishing areas of Northern Australia, where divers spend long times underwater using standard diving equipment. In-water air treatment continued to be used, in the absence of available recompression chambers.

Despite the value of in-water air recompression therapy, there are many problems associated with it that are well recognized by both divers and medical advisers. First, the majority of amateurs or semi-professional divers do not carry the compressed air supplies or compressor facilities necessary for the extra decompression. Most have only scuba cylinders, or simple portable compressors that will not reliably supply divers (the patient and his attendant) for the depths and durations required.

What's more is that environmental conditions are often not conducive to in-water air treatment. The depths required for these treatments (often as deep as 50 msw/165 fsw) can usually only be achieved by returning to the open ocean, where the advent of night, inclement weather, rising seas, tiredness and exhaustion, and boat safety requirements, make the choice of in-water treatment a very serious decision. In addition, because of the considerable depths and time involved, hypothermia as a result of wet suit compression becomes likely. Seasickness in the injured diver and the diving attendants and the boat tenders, is also a significant problem. Nitrogen narcosis produces added difficulties in the diver and the treatment. Because of these difficult circumstances, treatment must often be aborted, resulting in DCI in the attendants, and aggravating it in the diver.

In-water air treatment of DCI is not to be undertaken lightly, however, in the absence of a recompression chamber or other options, it may be the only treatment available to prevent death or severe disability. Fortunately, a newer method has been developed that addresses many of the problems associated with air treatments.

Oxygen Therapy

The value of substituting oxygen for air, in recompression chamber treatment has been well established. The pioneering work of Yarborough and Behnke (1939) eventuated in the oxygen tables described by Goodman and Workman (1965). They received widespread acceptance, with revisions and modifications they are now incorporated in oxygen treatment tables of most Navies.

The advantages of oxygen over air tables include; increasing nitrogen elimination gradients, avoiding extra nitrogen loads, increasing oxygenation to tissues, decreasing the depths required for the exposure time and improving the overall therapeutic efficiency. The same arguments are applicable when one compares in-water air and oxygen treatment.

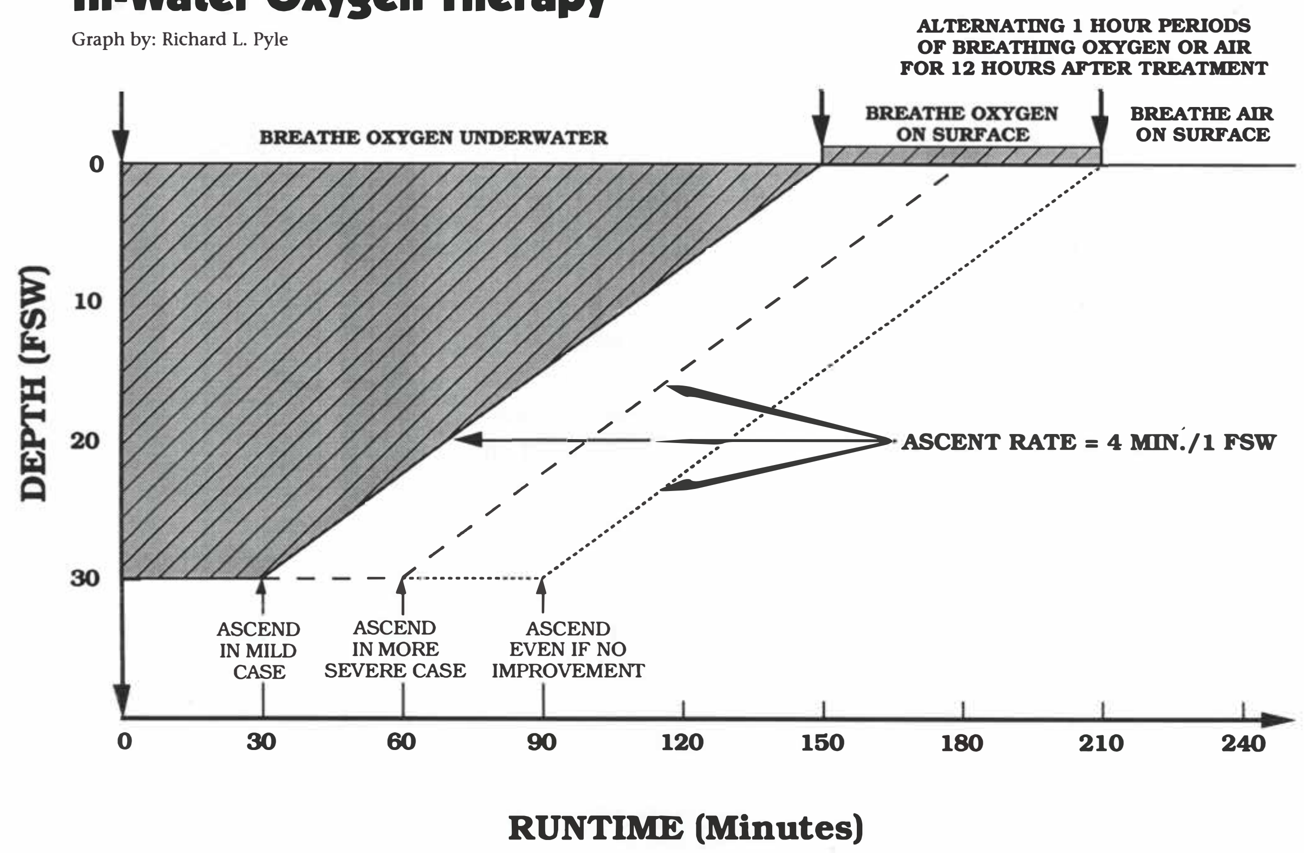
Australian In-water Oxygen Therapy

In response to an urgent need for managing cases in remote locations, both time and distance from hyperbaric facilities, oxygen therapy was first applied to the in-water treatment of decompression illness in Australia, in 1970. Because of the success of this treatment and its ready availability, it became known and practiced, even when experts were not available to supervise it.

The physiological principles on which this treatment is based are well known and not contentious, although the indications for treatment have caused some confusion. Like conventional oxygen therapy tables, it was first applied mainly for the minor cases of DCS, but was subsequently found

In-Water Oxygen Therapy

Graph by: Richard L. Pyle



of considerable value in serious cases. The techniques and equipment for Australian in-water oxygen therapy were designed to increase safety, ease and ready availability, even in medically unsophisticated countries (see box). It is now in widespread use in the Pacific Islands and the northern parts of Australia. It spread to the colder southern waters of Australia, where it is now used by abalone divers who sometimes dive in areas difficult to service by conventional transport. It has also been included in certain diving manuals (Table 81 & 82 in the Royal Australian Navy Diving Manual and has been modified by allowing the use of oxygen rebreathing equipment, in the current US Navy Diving Manual. The French have had a very similar table (Comex12) which was immediately applicable to underwater use, and some Italian groups claimed to have employed the full US Navy oxygen therapy tables underwater - although how they managed this is not clear.

The original Australian in-water oxygen procedures and tables seem simpler and less likely to cause problems for the general diver population than these various alternatives, however, other procedures have evolved. Hawaiian commercial divers have included a **deep "air" spike** prior to the underwater oxygen treatment, in an attempt to either force bubbles back into solution or to allow bubbles trapped in arteries to transfer to the venous system.The relative value of this additional deep air dip is subject to some controversy and discussion, and its value remains to be clarified (*Note that the deep "air" spike to 50 msw/165 fsw used in the USN 6a recompression table appears to be increasingly falling "out of favor" in U.S. treatment circles due to problems of additional nitrogen loading and other complications. Many leading edge facilities are now using enriched air nitrox, and or heliox, in place of air for these treatments—ed.)*

In-water Oxygen Treatment Procedures

Australian In-Water Oxygen Therapy (Runtime in minutes)

Depth msw	Mild	Severe	Severe w' Extension
9	30	60	90
8	42	72	102
7	54	84	114
6	66	96	126
5	78	108	138
4	90	120	150
3	102	132	162
2	114	144	174
1	126	156	186
Total Time	2hrs. 6 min.	2 hrs. 36 min.	3 hrs. 6 min.

Oxygen should be supplied at maximum depth of 9 msw (30 fsw), from a surface supply system. The ascent is commenced after 30 minutes in mild cases, or 60 minutes in severe cases, if significant improvement has occurred. These times may be extended for another 30 minutes, if there has been no improvement. The ascent is at the rate of 12 minutes per metre (4 minutes/foot). ***A diver attendant should always be present, and the ascent controlled by the surface tenders.*** The duration of the tables range from 2 hours 36 minutes or 3 hours 6 minutes depending on the treatment options used.

After surfacing the patient should be given periods of oxygen breathing, interspersed with air breathing, usually on a one hour on, one hour off, basis, with respiratory volume measurements and chest X-ray examination if possible. The treatment can be repeated twice daily, if needed.

The equipment required for this treatment is similar to that used in a surface supplied oxygen decompression system with some important differences. In the case of an in-water treatment, a G size cylinder (220 cubic feet or 7000 litres) of medical oxygen is probably adequate though specific requirements can easily be calculated. This is usually available from local gas supply companies or hospitals, although in some cases industrial oxygen has been used. ***For a diver at rest, breathing this volume of oxygen at a depth varying between 9 metres (30 feet) and the surface is usually insufficient to produce either neurological (CNS) or respiratory oxygen toxicity*** Note that all equipment used with pure oxygen must be rated for oxygen service. Also, whenever oxygen is given, the cylinder should be turned on slowly and the flow commenced, before it is given to patients or divers.

A 2-stage regulator, set at 550 kPa (80 psi) is fitted with a safety valve, and connects with 12 metres (40 feet) of supply hose. This allows for 9 metres depth, 2 metres from the surface of the water to the cylinder, and 1 metre around the diver. A non-return valve is attached between the supply line and the full face mask. ***The full face mask is critical as it enables the system to be used with a semi-conscious or unwell patient. It reduces the risk of aspiration of sea water, allows the patient to speak to his attendants, and also permits vomiting to occur without obstructing the respiratory gas supply.***

The supply line is marked in distances of 1 metre from the surface to the diver, and is tucked under the weight belt, between the diver's legs, or is attached to a harness. The diver must be weighted to prevent drifting upwards in an arc by the current.

A Field Treatment Option For Technical Divers

It was originally hoped that the underwater oxygen treatment would be sufficient for the management of minor cases of DCI, and to prevent deterioration of the more severe cases while suitable transport was being arranged. When the regime is applied early, even in the severe cases the transport is often not required. It is a common observation that improvement continues throughout the ascent, at 12 minutes per metre. Presumably the resolution of the bubble is more rapid at this ascent rate than its expansion, due to Boyle's Law.

Certain other advantages are obvious. During the hours of continuous hyperbaric oxygenation, tissues become effectively de-nitrogenated. Bubbles are initially reduced in volume, due to the hyperbaric exposure and Boyle's Law, and the resolution is speeded up by increasing the nitrogen gradient from the bubble. Attendant divers are not subjected to the risk of DCI or nitrogen narcosis, and ***the affected diver is not going to be made worse by premature termination of the treatment if this is required*** *(for example, in order to transport the diver—ed.).* In addition, hypothermia is much less likely to develop, because of the greater efficiency of the wet suits at these minor depths *(Note that the majority of technical divers utilize dry suits even in relatively warm water, so hypothermia is unlikely to be a major issue in most cases. See discussion below—ed.).*

SUMMARY

AUSTRALIAN IN-WATER OXYGEN THERAPY

This technique may be useful in treating cases of decompression illness in localities remote from recompression facilities. It may also be of use while suitable transport to such a centre is being arranged.

In planning, it should be realized that the therapy may take up to 3 hours. The risks of cold, immersion and other environmental factors should be balanced against the beneficial effects. The diver must be accompanied by an attendant.

Equipment

The following equipment is essential before attempting this form of treatment:

1. Full face mask with demand valve and surface supply system or helmet with free flow.
2. Adequate supply of 100% oxygen for patient, and air for attendant, typically about **200** cf per treatment.
3. Shot with at least 10 metres of rope (a seat or harness may be rigged to the shot).
4. Some form of communication system between patient, attendant and surface, preferably voice communications.

Method

1. The patient is lowered on the shot rope to 9 metres (30 fsw), breathing 100% oxygen.
2. Ascent is commenced after 30 minutes in mild cases, or 60 minutes in severe cases, if improvement has occurred. These times may be extended to 60 minutes and 90 minutes respectively if there is no improvement.
3. Ascent is at the rate of 1 metre every 12 minutes. Staging may be applied where applicable.
4. If symptoms recur remain at depth a further 30 minutes before continuing ascent.
5. If oxygen supply is exhausted, return to the surface, rather than breathe air.
6. After surfacing the patient should be given one hour on oxygen, one hour off, for a further 12 hours.

The site chosen can often be in a shallow protected area, reducing the influence of weather on the patient, the diving attendants and the boat tenders. Communications between the diver and the attendants are not difficult, and the situation is not as stressful as the deeper, longer, in-water air treatments, or even as worrying as in some recompression chambers.

When hyperbaric chambers are used in remote localities, often with inadequate equipment and insufficiently trained personnel, there is an appreciable danger form both fire and explosion. There is the added difficulty in dealing with inexperienced medical personnel not ensuring an adequate face seal for the mask. These problems are not encountered in in-water treatment.

In spite of these advantages, in-water oxygen recompression is not applicable to all cases, especially when the patient is unable or unwilling to return to the underwater environment. It is also of very little value in the cases where gross decompression staging has been omitted, or where the disseminated intravascular coagulation syndrome has developed. The author would be reluctant to administer this regime where the patient has either epileptic convulsions or clouding of consciousness. Reference to the case reports reveals that others are less conservative.

One of the common myths in Australia, is that in-water treatment is applicable to the semi-tropical and tropical areas, where it was first used, but not to the southern parts of the continent, where water temperatures may be as low as 5° C (41° F). There are certain inconsistencies with this statement. First, if the diver developed DCI while diving in these waters, then he or she is most likely to already have an effective thermal protection suit available. Also, the duration underwater for the oxygen treatment is not excessive, and is conducted at a depth at which even wet suits provide effective insulation. If the diver is wearing a dry suit, the argument is even less applicable. The most effective argument is that in-water oxygen recompression is used, often very successfully, in these very areas.

Some claim that the in-water oxygen treatment is useful only when there are no transport facilities available. Initially this was also our own teaching, but with the logic that comes with hindsight, ***a three hour gap is all that is needed between the instituting of in-water oxygen therapy and the arrival of transport, to be able to effectively employ this procedure.*** It is probably just as important to treat the serious cases early, even though full recovery is unlikely, than to do nothing and watch the symptoms progress during those hours. Note that transport should be sought while the in-water treatment is being utilized,especially in serious cases.

There has also been a concern that if this technique is available for treatment of DCI, other divers may misuse it to decompress on oxygen underwater and perhaps run into subsequent problems. This is more an argument in favour of educating divers, than depriving them of potentially valuable treatment facilities. *(Note that in-water oxygen decompression has become a "community standard" among technical divers in the U.S. and other parts of the world, though it is not an accepted procedure for recreational divers who are not trained in decompression diving.—ed.).* With the same rationale, one could use this argument to totally prohibit all safety equipment, including recompression chamber, and thereby hope to circumvent all diving related problems.

It has also been argued that this treatment is unlikely to be of any value for those patients suffering from air embolism. Such may well be the case. The treatment was never proposed for this, and nor was it ever suggested that the in-water oxygen treatment should be used in preference to recompression facilities where they exist and are easily accessible to the diver. It is, however, possible that the treatment may be of value for cases of mediastinal emphysema, and perhaps even a small pneumothorax.

In conclusion, in-water oxygen recompression is an application and modification of current treatment regimes. It is not meant to replace the formal treatment techniques of recompression therapy in chambers. It is an emergency procedure, able to be applied with equipment usually found in remote localities and is designed to reduce the many hazards associated with the conventional in-water air treatments. The customary supportive and pharmacological adjuncts to the treatment of recompression sickness are in no way avoided, and the superiority of experienced personnel and comprehensive hyperbaric facilities is not being challenged. In-water oxygen treatment is considered as a first aid regime, not superior to portable recompression chambers, but sometimes surprisingly effective and rarely, if ever, detrimental.

Dr. Carl Edmonds is regarded as the leading authority on in-water treatment of decompression illness, and has made major contributions to diving medicine in a variety of capacities including; Director of the Diving Medical Centre, Sydney, Australia, consultant in underwater medicine to the Royal Australian Navy, past president, South Pacific Underwater Medicine Society, Officer in charge, Royal Australian Navy School of Underwater Medicine. Dr. Edmonds can be contacted at: North Shore Medical Centre, 66 Pacific Hwy., St. Leonards 2065, Australia.

This article is derived from Diving and Subaquatic Medicine, 3rd edition, 1991, published by Butterworth Heinemann, 80 Montvale Ave, Stoneham, MA 02180, USA

In-water Recompression: The Hawaiian Experience

by Richard L. Pyle

A little over ten years ago, Frank P. Farm, Edwin M. Hayashi, and Edward L. Beckman, from the Hyperbaric Treatment Center at the University of Hawaii School of Medicine conducted a survey of Hawaiian diving fisherman. The purpose of the survey, which was part of a Sea Grant Research project, was to chronicle the diving practices of Hawaii's fisherman, and to investigate their usage of in-water recompression therapy methods for the treatment of decompression illness (DCI). These fisherman, who regularly made five to eight dives per day, had collectively made over a *quarter of a million* dives at the time of the survey. As diving fisherman, their work entailed multiple daily exposures to 140-350 fsw (43-107 msw), followed by a shallow dive at the end of the day. With these profiles in mind, it should come as no surprise that every one of them had suffered DCI at least once in their careers. In fact, most of them had experienced DCI many times; so many that it was considered part of the job— an occupational hazard. To deal with this hazard, these diving professionals had, over the years, developed informal methods of in-water recompression therapy.

The survey revealed that these divers had utilized in-water therapy to treat DCI 527 times, and that the treatment completely eliminated DCI symptoms in 462 (88%) of the cases. In 51 of the remaining 65 cases, the divers had improved to the point where they opted not to seek further treatment and fully recovered in a day or two. The severity of the DCI symptoms treated with in-water methods ranged from mild shoulder pain to paralysis and other neurological dysfunction. The exact treatment methodology varied from diver to diver and there was no set standard. The divers included in the survey had made an *average* of 11,000 career dives (one had made over 23,000 dives), and had developed their diving regimes and in-water treatment methods by trial and error.

The somewhat remarkable results of the survey prompted the researchers to further investigate the effectiveness of in-water recompression therapy for use as an immediate, emergency treatment for DCI. Citing studies of bubble dissolution, growth dynamics and physiology, they attributed the high success rate of the in-water therapy to *immediate* recompression of the afflicted diver. They pointed out that the effectiveness of recompression therapy is greatly enhanced if recompression occurs *within five minutes* of the onset of symptoms.

The results of the survey were compiled in a report published by Sea Grant in 1986 (University of Hawaii Sea Grant Technical Paper UNIHI-SEAGRANT-TT-86-01). Melding the wisdom accumulated from the immense diving experience of the surveyed divers, and the results obtained from scientific studies on the physics and physiology of DCI and recompression therapy, Farm, Hayashi and Beckman formulated a list of conclusions and recommendations for Hawaii's commercial fisherman including a **strong recommendation that oxygen be incorporated into in-water recompression regimes** following the *"Australian Method"* developed by Dr. Carl Edmonds (see preceding article), or a modified version that was termed the *"Hawaiian Method" (Note that the Hawaiian Method includes a "deep dip on air" to 165 fsw (50 msw) and, in the opinion of many authorities, is not recommended for technical divers, due to the logistics involved, and the fact that the additional nitrogen gas loading may outweigh the benefits of the additional pressurization—ed.)* They also point out that **many factors should be considered before opting for in-water treatment, and it should be considered *only* as an emergency treatment. Subsequent treatment at a hyperbaric facility should be sought in *all* cases, regardless of the outcome of the in-water therapy.**

As a result of the work done in Hawaii, there appears to be an interesting contrast between the attitudes of Hawaiian divers and those elsewhere. Whereas the practice of in-water recompression is either "unheard of" or strongly discouraged in many (most) parts of the world, it is considered a part of diving among Hawaii's diving fisherman and others, and there seems to be little controversy on the subject. Certainly not all divers are aware of it or consider it useful, but few dispute that it is a viable field option. Most of those who are aware of in-water therapy are also aware of the dangers associated with it. Even so, among many groups, there is seldom much deliberation at the onset of DCI symptoms; conditions are assessed, and more often than not, in-water recompression is practiced, often with good results.

It's not that proper treatment is unavailable; Hawaii is home to an excellent hyperbaric facility which is only hours away from just about anywhere in the state. Hard-core Hawaiian divers simply have a different mindset with regards to the practice of in-water recompression. They view it as a viable procedure which has saved many lives, perhaps even their own.

Richard Pyle, aquaCorps field editor, is an ichthyologist and fish collector working with the Bishop Museum, Honolulu, and is currently completing his graduate studies at the Univ. of Hawaii. He can be contacted at: PO Box 19000A, Honolulu, Hawaii 96817. Fax: 808-841-8968.

incident reports

Double Fatality on the "U—Who"

by Dennis J. Willis

On October 12, 1992 two highly experienced cave divers, Chris Rouse and Chris Rouse, Jr., died exploring a U-boat wreck known as the "U-Who" offshore New Jersey. Both were trained in deep diving on air and mixed gases. This accident has had a major impact on the technical diving community. A formal report is being prepared, but aquaCorps felt it important that a preliminary report be issued at this time.

The Rouses were diving with double 104's filled with air for their travel and bottom mix. Each diver also carried an 80 cu ft aluminum tank of 60% oxygen-enriched air intermediate decompression mix, and a 72 cu ft steel tank of 100% oxygen.

After clipping off 3 of the 4 stage bottles (probably one EAN and two oxygen) near the anchor line, they proceeded to their point of penetration where a tie off was made and the 4th stage bottle (of EAN) was clipped. Shortly after entering the wreck Chris Jr. was trapped by falling debris; loosened silt reduced the visibility to nearly zero. Chris Sr. entered or was already just inside the wreck and began to dig out Chris Jr., further reducing the visibility. After Chris Jr. was freed the two divers were unable to follow their line out; according to statements by Chris Jr., and examination of their equipment, they evidently began exploring with line for a new exit. During their exit

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Big Bend

by Bernie Chowdhury

***Editor's note:** Due to operational problems, the author omitted staged decompression after a 53-minute dive to 150 fsw and suffered acute neurological DCI. A moderately experienced deep diver, he attributes the accident to diving while ill on medication, and to fatigue, which predisposed him to nitrogen narcosis and the concomitant disorientation. As a result, he did not adhere to a precise dive plan and opted to make a direct ascent to the surface when he could not locate his stage bottle or the anchorline.*

As I lay limp and powerless on the *Seeker's* gearing-up platform, I took in the efforts of the crew and passengers to save my life. Both of my Aladin Pro dive computers were screaming in protest at my having missed more than 99 minutes of decompression. My first stage stop was scheduled for 50 fsw.

The pain was excruciating. I felt like the guy in the movie *Alien*—you know, when the Alien pops out of his stomach during dinner. It felt like my insides were being rearranged. As time passed, my thoughts centered increasingly on the arrival of the Coast Guard rescue chopper and getting to a recompression chamber. I was spared the noise of computers beeping and the captain bellowing as I went completely deaf. I drifted in and out of consciousness and floated to a numb and painless world.

"Routine" dive

The dive had gone smoothly at first. I dropped an oxygen stage bottle at the anchor, at the wreck's stern. My buddy, Ed, and I separated to

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Confessions of a Mortal Diver: Learning the Hard Way

by Richard L. Pyle

***Editor's note:** In July 1986, after repetitive air dives to 250 fsw and 140 fsw off Palau, the author suffered acute neurological DCI symptoms. He was treated in a chamber on Palau after several hours of unsuccessful in-water air recompression, then transferred to a hyperbaric facility on Guam. His condition improved slightly after two treatments there, after which he was taken to the chamber in Hawaii.*

Thus began the long series of treatments at Honolulu's Hyperbaric Treatment Facility. The first few treatments were 12 hours in duration, but most of the rest were standard eight-hour "Hyperbaric Oxygen" (HBO) treatments. These consisted of an initial "spike" to a simulated 220 fsw, a slow ascent to 60 fsw breathing a special enriched-air nitrox mixture, four 20-minute periods of breathing pure oxygen (with five-minute "air breaks" in between) at 60 fsw, a long haul on pure oxygen at 30 fsw, then a very slow ascent to the surface. I was given one such treatment per day, then taken to a nearby hospital to spend the night.

Through intensive physical therapy, my legs increased in strength. I regained control of my bladder, eliminating the need for a catheter. I began walking up and down stairs for additional exercise. I had many long discussions with Dr. Robert Overlock regarding the theory and practice of recompression treatment and the physiology of bends. He explained that my injury was analogous to a shotgun wound in my spinal cord and made certain that I understood that many of my nerve cells had died forever. My recovery was not a result of new nerve growth, but rather a result of my brain learning new nerve pathways to send signals to the rest of my body. He explained how I was now much more susceptible to DCI, that a subsequent

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"U—Who"

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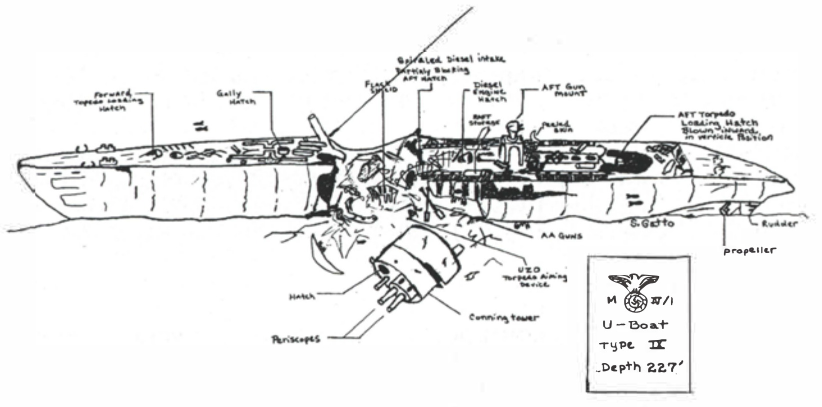

The wreck of the German U-boat, the "U-Who" as she sits off the coast of New Jersey. Illustration Steve Gatto

it appears Chris Jr. experienced some trouble with his primary regulator and switched to his secondary regulator, but it was taking in water. At this time Chris gave Chris Jr. his secondary regulator and they continued out of the wreck. After finding the exit Chris Jr. noted it had taken 31 min for them to get out, 11 min. longer then their planned bottom time. They were able to locate only one stage bottle (EAN60), and were so low on air with no more time at depth to search for the anchor line or the remaining bottles they left for the surface. They may have attempted some decompression in mid-water.

They arrived at the surface 41 min. into the dive. Chris Sr. had limited use of his arms and hands. His eyes were glassy and he appeared calm although confused. While being assisted by surface help he went into respiratory failure, and 20 min later cardiac failure occurred. CPR was started immediately and continued to the hospital (apx. 3.5 hr later). He was pronounced dead on arrival at Bronx Municipal Hospital. While at the surface Chris Rouse Jr. was hit by the tossing boat and his DIN adapter was sheared off the manifold; he lost a large amount of air before surface help could close the valve. He was quite alert on the surface, yelling about the ordeal, but he was paralyzed and had no feeling from the waist down. After reaching the hospital he was placed in the chamber on USN Treatment Table 6A, during which he reportedly regained some feeling in his legs along with an increased level of pain. Early in the first air break at 1.9 atm (30 fsw) his heart stopped and resuscitation was unsuccessful.

Their bottom timer displayed a max depth of 223 fsw for 41 min. Chris's air tanks had 250 psi, and Chris Jr. had 150 psi. The one stage bottle recovered had 1200 psi.

The investigation into this accident is still ongoing and a detailed report is being prepared for publication. Readers are reminded that hasty conclusions may be premature.

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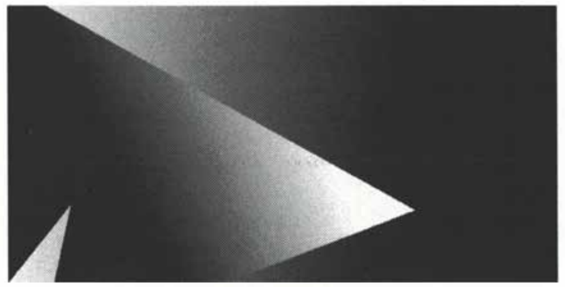

Big Bend

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explore different areas. I repeatedly sensed that I should turn the dive and head for the anchorline but, captivated by the wreck, I resisted the urge to terminate the dive. I eventually swam to the bow.

I saw a second light as Ed entered the bow. We exited together. Ed signalled for an ascent on an upline that the crew tied off on a previous dive. Instead, I swam off toward the stern to pick up my oxygen cylinder.

Finding a current on top of the wreck, I dropped to the debris field and swam the 350 feet to the stern. I couldn't find the anchorline or my stage. I discounted landmarks that I had seen on previous dives, because they were on the opposite side of the wreck from where I thought I was. Exhausted, I swam on top of the hull until I came to the end of the wreck. I realized I was at the bow, having swum around the entire 500-foot-long wreck. Although I had air left in my tanks, I opted for a free ascent directly to the surface.

Chopper ride, chamber ride

When the chopper came, I stumbled over to the basket and was helped in. There's not much you can do when you're in lots of pain and riding it out. I was extremely uncomfortable and couldn't do anything but lie there quietly. In the hospital, I gave them information and watched as a nurse wrote it down. The examination seemed to take a long time, during which I felt like shouting, *"Get me to the chamber."* I refrained and made it to the chamber and through the uncomfortable ride anyway.

Wheeled to a hospital room afterward, I felt finished, both mentally and physically. My hearing had returned but was not normal. My body ached. I couldn't walk.

Learning to walk

As the days progressed, I learned to walk again. At first, what normally would have been a few paces to the bathroom consisted of stumbling drunkenly from chairhold to bedrailhold to wall to door. I learned to negotiate this even though the room spun maddeningly. I learned to walk in a shuffle, a few feet at first, then to the bathroom unassisted (a major victory), to the hallway and back, and then varying lengths down the hallway. Rapid progress would have caused me to keel over from the force of momentum.

After five days, I was able to walk around the ward while swerving only slightly.

It was certainly humbling. The 150-foot dive was something I considered routine. Ironically, had this been the *Andrea Doria*, I wouldn't have made the dive, because I wasn't feeling well. The experience taught me that there is no such thing as a routine dive."

Bernie Chowdhury is an active wreck and cave diver, and writer who has recently compiled an analysis of wreck diving accidents in conjunction with the Univ. of Rhode Island, National Underwater Accident Data Center. He can be contacted at:

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EAN 32:
"Safer Not Safe"

by Mark R. Mondano

After more than 20 years of diving, I can attest that not all dives are uneventful. Many unusual and unexpected occurrences have instilled a sound regard for the risks of scuba diving. Despite some extreme air diving exposures in the course of my diving, I had been fortunate to escape the consequences of decompression illness. Then one dive ended this unblemished record.

I don't drink or smoke, and the only medication I had used within months of this dive was ibuprofen (Advil). I exercise regularly, and was not sleep deprived. The plan was to scout some reef for the upcoming Florida lobster season. My first dive of the day— my first in 14 days—was on a reef in 90 fsw (27 msw). Visibility was 40 ft with no current on the bottom. The majority of the dive was conducted at a depth of 80 to 85 fsw (24-26 msw), with the deepest excursion to 96 fsw (29 msw). Total bottom time was 19 minutes. My swimming rate was moderate with no strenuous activity. At the beginning of my ascent, 8 minutes remained as allowable bottom time. I made my ascent in accordance with a variable ascent rate computer model and made a safety stop of one to two minutes at 15 fsw (4.5 msw).

Five to 10 minutes after surfacing, my right lower leg became numb. This was followed in rapid order by left leg numbness, right leg weakness, and then left leg weakness. I assumed a supine position and immediately began 100% 02 by demand mask (non-rebreather). Slight numbness was noted in the fourth and fifth finger of both my hands and a few seconds of dysarthria (difficulty speaking) occurred. Two minutes into the 02 treatment, only the lower limb weakness and numbness remained. These symptoms gradually improved. At 25 minutes after the start of 02 therapy all symptoms had disappeared. Intermittent 02 therapy (to conserve the supply) continued until I was transferred to an ambulance (which was not equipped to deliver 100 % 02!##!@!). Despite resolution of symptoms, chamber therapy was instituted two hours and 45 minutes after the first symptoms occurred. No further decompression illness occurred. No evidence of pulmonary barotrauma was discovered.

This dive was well within safety limits set by U.S. Navy tables and both of my computers. DCI can occur with air exposures such as the one described in this history. However, this case was unusual in that the dive was conducted on EAN32 (32% O2, balance nitrogen) which was analyzed after mixing and again before diving. This mix works out to an equivalent air depth (EAD) of approximately 78 feet for 19 minutes, a seemingly trivial exposure.

Several experts have implied that DCI is a statistical inevitability if one dives frequently enough. After several thousand previous dives, perhaps my number was up.

Dr. Mark Mondano is a wreck diver and anesthesiologist, with over 20 years of diving experience. He can be contacted at:

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Odds & EANs

Enriched air and oxygen are tools that can be used to improve decompression safety, as well as performance. To date, the decompression safety record for both enriched air and O2 have been good. However if these tools are misapplied, or used without the requisite knowledge, they can result in injury. Here are some examples of incidents that have occurred.

PROFILE:
: Deep Air w/O2 Followed by EAN Dive
Dive 1:
210 fsw (64 msw)/25 min. bottom time. Air, USN Extreme Exposure Tables. Total decompression 31 min. beginning at 30 fsw (9 msw), 26 min. O2 decompression.
Dive 2:
40 fsw (12 msw)/ 35 min. bottom time. EAN 38.
Diver thought he could reduce decompression by about 50% from the tables by using in-water oxygen. Note that as a comparison, Submariner Research Ltd. Air w/O2 tables would call for 57 min. of decompression with a first stop of 70 fsw, and 26 min. of O2. Surface interval (SI): 65 min.
Presentation:
Deep boring left shoulder pain onset 25 min. post second dive.
Treatment:
USAF modified USN Table 6 with extensions.
Outcome:
Total recovery

PROFILE:
"Mystery Mix (EAN)"
Dive:
85 fsw (26 msw)/45 min. bottom time. Unknown EAN mix.
Home brew topped off in series with other customers air cylinders (unknowingly by dealer). Final mix **not analyzed** by user prior to use (exact ending pressure not controlled). Diver stated that he believed O2 was equalized among other cylinders in series, thereby reducing the O2 content of his final fill.
Presentation:
Pain and tingling in left shoulder 10 min. post dive.
Treatment: Refused.

PROFILE:
Repetitive EAN Dive
Dive 1:
90 fsw (27 msw)/30 min. bottomtime. EAN 32. No decompression. SI: 60 min.
Dive 2:
90 fsw (27 msw)/30 min. bottomtime. EAN 32. No decompression. SI: 60 min.
Dive 3:
90 fsw (27 msw)/40 min. bottomtime. EAN 32. No decompression.
EAN mix filled at dealers by topping off O2 filled cylinders with air. Estimated mix, EAN 32-33. Final analysis not performed. The diver did not figure EAD (he did not know how to!) or use a table to calculate decompression. Stated he *"assumed that using EAN would prevent DCI."* Assuming his mix was an EAN 32 (EAD: 73 fsw/22 msw) and using the USN Air Tables, the diver omitted 63 min. of decompression on the three dives. The diver had been bent (limb pain DCI) the previous year and was successfully treated on a USN Table 6.
Presentation:
No symptoms prior to surfacing on dive #3. Diver complained of "not feeling right" 10 min. after his final dive, became unresponsive and laid down on deck. There was *no O2 available on the boat,* so the diver was rushed to the dock where he was placed on O2 by a waiting EMT. The diver was transferred to an HBO unit by helicopter and immediate treatment began. The diver was given two extended and modified USN Table 6 treatments, however he continued to deteriorate until complete lower limb paralysis set in, as well

U.S. / U.K. Sport Diving Decompression Illness Scorecard

	D.A.N. Statistics 1.		BSAC Statistics 2.	
Year	#Cases	% Neurological	#Cases	% Neurological
1988	268	60%	84	N/R
1989	391	64%	154	N/R
1990	459	62%	91	52%
1991	437	70%	115	53%
1992	N/R	N/R	42	64%

1. Communication from Diver's Alert Network, 10DEC92. Reflects total DCI (computer database) cases where reasonable follow-up could be conducted.
2. Reprinted from British Sub-Aqua Club's NDC Diving incidents Report 1992 with permission.

Confessions of a Mortal Diver

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hit would very likely occur in my central nervous system, and that I had used up just about all of the "extra" nerve pathways in my spinal cord. He made it clear, in no uncertain terms, that if I continued to dive, I would be much more likely to get bent, and that full recovery from such a hit wold be much less likely. Basically, he did his best to convince me to give up diving for good.

Beyond the chamber

After 28 treatments I could walk on my own (very slowly, and with a substantial limp), although I still had no sharp pain or hot/cold feeling in my legs. The increments of improvement in my condition with each passing day had diminished to the point where I really couldn't detect them. Finally, more than a month after the accident, the decision was made to stop the chamber treatments. I was afraid that my condition would remain that way forever. True, I could walk, and I was certainly in better condition than I had been a month earlier, but I couldn't run, I couldn't jump, and my body was still suffering from some serious impairment. But Dr. Overlock assured me that the chamber treatments were yielding diminishing returns and that only time would heal my wounds. He said the healing would continue for a couple of years, but he could not tell me how much my condition would improve.

As the months passed, my ability to walk continued to improve very slowly. With practice, I was able to conceal my limp and appear to walk normally, but it took a great deal of effort. Climbing stairs was not much of a problem, but coming down them was difficult. Even stepping off a curb required a great deal of concentration. I was able to contract the muscles in my leg fairly smoothly, but I was unable to relax them at a controlled rate. Also, my legs would occasionally convulse spasmodically and uncontrollably. The feeling in my legs did not improve as quickly—I still could not feel any sharp pain or distinguish hot from cold. I continued with an assortment of leg exercises, and my condition very slowly improved.

Back in the water

I limited my first post-bends dive, nearly a year after the accident, to a maximum depth of 25 feet. As the months passed, I slowly increased that to 60 feet, then 130 feet, always following an *extremely* conservative decompression profile. On my first post-bends dive to 180 fsw, I was very nervous. After a 10-minute bottom time, I decompressed for well over an hour. One of the effects of my impaired legs was that after long exposures to water, they would feel weak and numb. It was terrifying every time I surfaced from a deep dive with long decompression, because my legs would feel almost exactly the same as they had felt in Palau right after the accident. On the decompression line, I would continually monitor the coordination of my fingers by touching each finger-tip to my thumb in rapid succession. Every time we returned to the harbor after a dive, I would trot around the parking lot to determine if my legs were fully functional.

Two years after the accident, I was able to walk almost totally normally, and I could even jog reasonably well. The feeling in my legs had improved but was far from normal.

By December 1987, a year and a half after the accident, I had logged nearly 200 post-bends dives, more than half below 200 fsw. In all of these, I never experienced any neurological DCI symptoms.

It has now been six years since the accident. I've made well over 1,500 post-bends dives, more than two-thirds of which were in excess of 180 fsw. In addition, I've begun using mix to penetrate depths of more than 400 fsw. In all of this deep diving, I have not experienced any further DCI symptoms. And so it continues.

Lessons learned

In retrospect I now feel I understand the fundamental factor that led to my severe bends hit that sunny July 14th in Palau. It wasn't because I went too deep or stayed too long. It wasn't because of the decompression meter I was using. It wasn't even because my pressure gauge malfunctioned. Although these were all contributing factors, they were not the *fundamental reason* I got bent. The real reason was that I had a very bad attitude about deep diving. I got caught in a trap that snares many young, bold and "immortal" divers—the trap of overconfidence. Since I was continuously pushing the limits—and getting away with it—I felt overconfident about pushing the limits even further. I was sure that I would never get bent. I regarded all of the emphasis on safe diving practices and self discipline as "sport diver crap," and I felt as though I was exempt from following conventional guidelines. I was wrong—almost *dead* wrong.

So why, then, do I continue to dive deep? It would be naive of me to think that I have "learned my lesson." The risk of decompression sickness follows anyone who breathes gases at greater than one atmosphere pressure. That risk cannot be avoided, and it increases with increased depth of diving. Will I ever get bent again? To be honest, I don't know. Many friends and colleagues feel as though I'm living on borrowed time. Maybe I am. But at least I have changed my attitude about deep diving. I no longer view it as a test of my abilities or as a means to demonstrate my courage. Statistics of diving accidents suggest that I am more likely to get bent again, now that I've been hit once already. I'm not convinced that this is true, but whenever I find myself hanging on a decompression line after a deep dive, I always assume that it is.

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Delivering Oxygen To Suspected Diving Accident Victims

by Lalo Fiorelli

The first priority in a suspected dive accident is always to establish the ABC's (airway, breathing and circulation) followed by oxygen therapy. What's the big deal? Isn't it just a matter of opening a tank valve and putting a mask on a person's face? An oxygen-cleaned scuba regulator and cylinder is the best option anyway. Isn't it? Afterall, what are you going to accomplish with a tiny D or E pin indexed medical grade oxygen cylinder? These are the most frequently asked questions about the use of oxygen for treating suspected dive accident victims.

The standards of care surrounding this issue have been well established by DAN (Divers Alert Network) and have the blessing of the recreational diving agencies. They are also practiced by the EMT community, in areas where diving accidents and near-drownings occur. The goal of this therapy is not only to deliver 100% oxygen to the patient, *but to have the INSPIRED percentage of oxygen be as close to 100% as possible.* The only delivery method capable of delivering an inspired percentage of 100% is a demand system, preferably using a mask that covers both the mouth and nose. The option of choice is to use an oxygen demand regulator with a "tru-fit" mask on a pin indexed medical grade oxygen bottle. This delivery option is capable, on demand, of delivering up to 160 liters per minute (lpm), 5-6 cfm, to a patient at a 100% inspired oxygen level.

Though often utilized in the field, the use of an oxygen-cleaned scuba delivery system requires the patient to use a scuba regulator and breathe through the mouth. This requires a conscious, cooperative patient who can tolerate the regulator. In the case of an unconscious victim, noseclips or a scuba mask can be used. Field experience has shown that neither of these options is as effective and comfortable as a "tru-fit" mask. A further limitation to this system, in some cases, is that it only allows for only one patient at a time, depending on configuration. Most of the standard oxygen demand regulators have the capability to deal with multiple patients, and have both demand and constant flow delivery options.

What if there is no demand equipment in sight? THE MINIMUM RECOMMENDED "CONSTANT FLOW RATE" FOR THE THERAPY BEING ATTEMPTED IS 15 lpm (or about 0.5 cf/min.). This is necessary in order to achieve a sufficient inspired concentration of oxygen. The problem is that constant flow masks are designed with openings which allow air to enter the delivery system thus diluting the inspired percentage of O2. Lesser flow rates simply do not deliver enough oxygen to the patient during the breathing cycle. It is estimated that fully 90% of the emergency oxygen equipment in the field is inadequate in this regard. Most have either fixed flow attached regulators or medical regulators capable of only 6-8 lpm—*half of the minimum flow*—to accomplish the therapy at the standard of care level.

Note that the only time the demand system is not preferred is with a patient who can not tolerate the mask options available for use with this system, if there is more than one patient and only one demand valve is available, or for a non-breathing victim where supplemental oxygen must be provided during CPR ventilations.

Assuming your equipment is capable of delivering a minimum of 15 lpm, the best delivery option is a non-rebreather mask. This mask has a reservoir bag, and with both exhalation ports having flapper valves installed, is capable of delivering an inspired oxygen percentage of 90% to the patient. If it is a non-rebreather mask with only one exhaust flapper valve, the inspired oxygen levels fall to about 60%. If a pocket mask is used, inspired oxygen percentages fall to the 30-50% range. Mask options and characteristics are shown in the table above.

t.1 Delivery Options

Flow Type	Mask	% Inspired O_2
Demand	Trufit	100%
Demand	pocket	95-100%
Constant	non-rebreather	90%
Constant	pocket	30-50%

One last point. There are many factors involved in providing oxygen to suspected dive accident victims not discussed here. The purpose of this article is to demonstrate the need for training, not to provide a user's guide. Providing oxygen to suspected accident victims has potential legal and moral consequences. If provided in the manner established as the standard of care, patients will receive the maximum benefits from the attempted therapy, and the provider's moral and legal position is unimpeachable.

Lalo Fiorelli is a Managing Director of the Cross Foundation. He is an oxygen instructor for both DAN and PADI, a full cave instructor (NACD), an ANDI and IAND enriched air instructor, and has been active in the technical community since 1986. He can be contacted at:

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Odds & EANs

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as other neurological symptoms. The diver was transferred to a large University hospital where a USN Table 7 "saturation" treatment (50 plus hours) was performed. Serious neurological residual damage remained. Further treatment is expected with a questionable prognosis.

PROFILE:
"Failed"
In-water Air Recompression
Dive 1:
75 fsw (23 msw)/ 40 min. bottomtime. Air.

Diver surfaced post dive with the onset of left shoulder pain and non-specific abdominal discomfort. After waiting about 60 min., the diver re-entered the water to conduct, "in-water air recompression" to 65 fsw (20 msw), PO2=.62 atm, for 25 minutes. Upon exiting, diver lost consciousness and fell, striking his head. The diver was evacuated to a trauma center by helicopter, and then transferred to a hyperbaric facility.

Presentation:

Unconsciousness. Vital signs stable with some downward fluxations. Diver given extended 60 fsw treatment with little relief. Patient transferred to intensive care unit where slow resolution of symptoms occurred over one week period.

The attending medical personnel believe that the in-water air recompression exacerbated nitrogen loading, and allowed "offending" bubbles (via compression) to bypass "pulmonary filters" and pass into arterial system, producing AGE upon ascent to the surface.

Special thanks to Andrew R. Mrozinski, EAN instructor, DAN O2 instructor trainer, and senior therapist at St. Mary's Hospital Hyperbaric Unit, West Palm, Florida, for providing this information. Mr. Mrozinski can be contacted at
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corps letters

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New Jersey coast, and the *Empress of Ireland* (145 fsw/44 msw) in the frigid waters of the St. Lawrence Seaway, Canada. The Rouses used state-of-the-art cave diving equipment with which they had many hundreds of hours of experience, and were extremely proficient with both air and mixed gas tables. Simply stated they were very, very good at what they did and they backed it up with experience in virtually every kind of diving environment imaginable, except for ice. Chris Sr. didn't particularly relish the cold.

Photo Michael Menduno

Chris Rouse Sr.
July 91 R.V. Wahoo

Chris and Chrissie will be honored by all who knew them and were touched by their fervor for diving. The cave diving community feels their loss keenly; so much so, that with the consent of the original discoverers, the famed *"Hinkle Restriction"* in Devil's Eye cave system, High Springs, FL., has been renamed the *"Rouse Restriction." (Per their wishes, their ashes will be scattered at the restriction—ed.).* The management of Ginnie Springs will also be dedicating a plaque in their memory. For myself, I will continue to dive to celebrate the courageous and daring lives of my friends. I loved them very much.

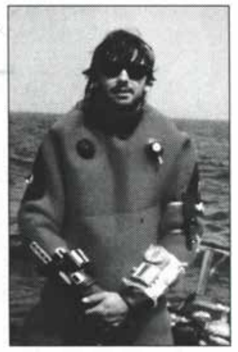


Photo Michael Menduno

Chris Rouse Jr.
July 91 R.V. Wahoo

Ian Jones
Doylestown, PA.

Turkish Contingent

The kinds of dives you treat in your journal are just what we make here in Turkey (deep/ deep wreck). We have a lot of interesting shipwrecks in our seas sunk since 1900, including two intact, 1200 ton submarines with equipment inside (80-90 msw) that nobody tries to dive. We make frequent dives to 60-70 msw and rarely to 80 meters with a maximum of 100 meters for me, and 114 meters for another Turkish diver on air. We sometimes breathe oxygen after these dives for safety. Here there is no organization or dive clubs for organizing such serious expeditions to do this kind of diving.

Asim Karscakar
Istanbul, Turkey

Northwest Tekkies

Having completed an IAND trimix program in California at Ocean Odyssey with my friend Eric, I just wanted to let you know that technical diving now at least has a toehold in the Pacific Northwest. I put my training to good use as soon as I got back to Washington, doing a couple of deep practice dives on the passenger liner, the *S.S. Governor*. The *Governor* is our answer to the *Andrea Doria* although somewhat smaller at 400 feet. She went down in 1921 after being rammed, and rests in 250 fsw (76 msw) of cold, dark, fast water in the middle of the main Puget Sound shipping channel. Everything she carried is still there. Puget sound is almost totally untapped as a wreck diving resource—there are enough deep virgin wrecks to keep a diver busy for years.

James R. Negris
Mukilteo, WA.

Mix Technology:

An Apple among IBMs?

If *technical Diver* confuses other aquaCorps readers as much as it confused me, you may be in trouble and I'm a Sun workstation user. You may be narked by your passion and expertise. Let me ask you, *"Are you looking to be a financial success or are you hoping to simply help defray the costs of your own (mixed gas) diving?"* I am afraid that from my perspective, you are boxing yourself into an esoteric success and financial failure.

Would it be better (financially) to ascend a few feet into the more mundane world of diving deeper on air for the time being, and evolve towards other breathing mixtures as they gain in popularity? Even PC's did not achieve success overnight. It took years of declining costs, increasing standardization and customer (business) acceptance for them to become economically viable.

Are the economics of mixed gas such that it will gain popularity quickly enough to insure your success? How many mixed gas dives per year will even well-heeled divers be able to afford? Consider the fact that a well known wreck diver up here looked for a cheap way out when his tank bands rusted through recently, or the fact that I still dive my Tekna regulator!

Would you do better to address the needs of those who regularly dive in the 120-180 fsw range but do not have the money or the desire to *push the envelope*? Isn't that the root of aquaCorps success? I think *aquaCorps/technical Diver* has an identity problem. But then again, you might be on your way to becoming the Steve Jobs of technical diving.

Bill Schmoldt
Brielle, New Jersey

Progressive Training

I am very technically oriented (holding a B.S. in Chemical Engineering), just completed my nitrox certification course and am extremely interested in expanding my skills in technical diving. The information I'm looking for is not only in regard to agencies and dive shops that offer training, but the appropriate progression of steps in that training. I have been diving moderately deep by recreational standards, but have never been deeper than 110 fsw (33 msw) or have any perception as to my susceptibility to nitrogen narcosis. Any information you could provide along these lines would be appreciated.

Robert Martin
Astabula, OH.

Unfortunately, at present there is no well defined transition path from recreational to technical diving, though an enriched air course is a good first step. Most individuals have gotten where they are through the "apprenticeship method," i.e. regularly diving with others who already have the knowledge and experience. Probably the single best way to begin to expand your technical diving knowledge and skills is to take a full cave diving course. And of course, do a lot of diving.

The Business of Diving

Undoubtedly the adventurous diving community will be using gas mixes more and more. This is the subject of great interest to us as a business, and I feel that we should be looking at the issue more thoroughly for our long term survival.

John R. Ellis
Seaways Inc./BSAC School
Truro, Cornwall, U.K.

Corrections:

Perpetual Motion

I noticed in your quote by Rick Freshee, SportDiver Magazine (aquaCorps N3, *"Mix,"* pg.23) Rene Buzzoz (the first U.S. "aqualung" distributor) was misspelled. It should be "Bussoz." It's a small thing that only a few would notice, but why continue an error that was started by someone else.

Dr. Sam Miller
Anaheim, CA.

There's no good reason at all. Thanks.

Get it Right

For the second time you have informed your readers that 1 meter= 3.2568 ft. The Oxford English, Collins and Heinmann dictionaries, as well as my imperial/metric conversion calculator say 1 metre=3.2808 feet. It's not a significant difference, but aquaCorps should get it right.

Christian Gerzner
Matchum, NSW
Australia

You're absolutely right with regards to linear measures (And aquaCorps. Thank you.): 1 metre=3.2808 feet. The problem is that things get a bit sticky when using these measures as pressure units, which must take into account the density of sea water.

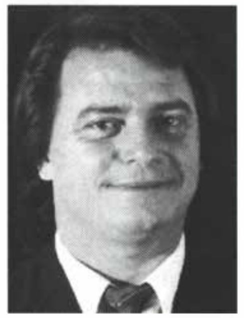
International convention defines:

1 atmosphere (atm) = 10.13 meters of sea water (msw),

based on a sea water density of 1.01972 gm/cm3 at 4° C. However, imperial pressure units are defined as: 1 atm = 33.08 feet of seawater (fsw), which equates to a density of 1.02480 gm/cm3 at 4° C. (Note that the density of pure "distilled" water is 1.00 gm/cm3 at 4° C.—ed.) Equating these expressions yields: 1 msw = 3.265 fsw. It's a strange world we live in.

Thank you for bringing this issue to our attention. We learned something in having to figure it out. Note that, beginning with this issue of the Journal, aquaCorps will be specifying depth in both feet and metres of seawater, using the 3.265 fsw.

"Thanks For The Fish"



A special thanks to Richard Stewart, publisher and editor of *Sport Diver Trade Journal* and *Traveler*, who helped us get out our last issue of the Journal, *aquaCorps N4, "MIX."* Wouldn't have made it without him. A tenacious denizen and pioneer of the dive publishing world, Stewart got his start in publishing over 16 years ago and has been putting out *Sport Diver* books ever since.

A Plug For SOLO

Watersport Publishing has just released its second printing of *"Solo Diving,"* by Robert Von Maier, first published soon after *aquaCorps N3, "SOLO"* hit the streets. Glad to know we're not alone. Unlike *"SOLO,"* at present, they have copies. (See tek.GUIDE, pg. 17, *Technical Information).*

Thank you for your interest and support. Your thoughts and feedback are extremely important to us. Please keep those letters and cards coming. M2

Note that reader letters have been edited for space considerations.

What does the future of self-contained diving hold?

BENT continued from page 3

more fruitful. In the commercial world, DCI is an expected occupational hazard, part of the job. If it is treated immediately (and properly), the consequences can be reduced to near zero, making it more of a painful inconvenience—*shit happens*—than a life or career-threatening ordeal.

The solution for the technical community is to expect and plan for DCI and be prepared to deal with it. Though efforts like the DANs field oxygen administration are an excellent beginning, more is needed. Author Bret Gilliam recently compared the situation to staging a highschool football game: "It would be stupid and irresponsible on the part of a coaching staff to not be prepared to treat injuries." Ouch. More specifically, in a recent editorial in the Associated Dive Contractors (ADC) magazine, *Underwater*, editor Cavett Hughes observed that technical diving was "severely deficient" in most of the basic consensual safety principles established by the ADC. She illustrated her point by way of example, correctly and incredulously pointing out that , "many of these deep dives have been done *not only* without a chamber on site, *but often hours away." (italic—ed.).*

Historically both the sport and scientific diving communities have resisted the move to on site chambers due to the lack of demonstrated need, economics, loss of operational flexibility and, in the case of some sport operators, the belief that providing additional "topside support", specifically a chamber, would increase assumed responsibility and, therefore liability. These factors appear to have been some of the initial hurdles that were faced in getting chambers installed at diving resorts, which has now become common practice.

Interestingly this world order is changing with the promulgation of the technical diving movement and the development of new methods and technologies. Rather than by decree from government or other regulatory agencies (which should and would be fought "tooth and nail" in any account), this changeover may be more a function of technology and its associated economics.

In-water oxygen therapy (see *"In-water Recompression,"* pg. 46) appears to be a promising, though perhaps transitional, solution to the problem of field treatment for technical divers. Historically, in-water recompression has suffered from significant stigma, and it is not without legitimate risk. Much of the reluctance to accept in-water treatment can be traced to the lack of knowledge, training, experience and equipment on the part of the recreational community. Though the concept will take some work to properly implement on a widespread scale, the technical community does not suffer from the same limitations as its mass market counterpart. In-water oxygen decompression is a standard practice, divers generally have adequate thermal protection (dry suits), and the proper equipment to implement in-water therapy is readily available.

Probably the most exciting news is the development of Kevlar-based portable chambers being pioneered by the UKs SOS Ltd (see *"Portable Chamber Technology, "* pg. 9, tek.GUIDE). Priced at around US$30,000, suddenly the prospect of conducting a *Doria* dive with an onsite chamber on board seems less remote, and given the nature of the beast, quite appealing. What's more is at least one other US company is reported to be rolling out a new portable this year priced in the US$18,000 range—about the cost of outfitting two technical divers, if you include their scooters. Gulp.

Will onsite chambers become the future community standard for technical diving? Perhaps the more relevant question is: who would you rather be diving with, "the haves" or the "have nots"? With regards to assumed liability, it is not unlikely that the issue may eventually be reversed. *"You conducted this operation without a chamber?"* Unrealistic? Just consider the hypothetical outcome of a court case today involving a technical operator who conducted a 300 fsw (92 msw) guided wreck dive on "air."

The bends remains a formidable issue in the development of technical diving if our objectives of improving safety are to be met. Perhaps the first step is simply to get it out in the light of day so that we can examine it better. That's what this issue of *aquaCorps* is all about.

Michael Menduno