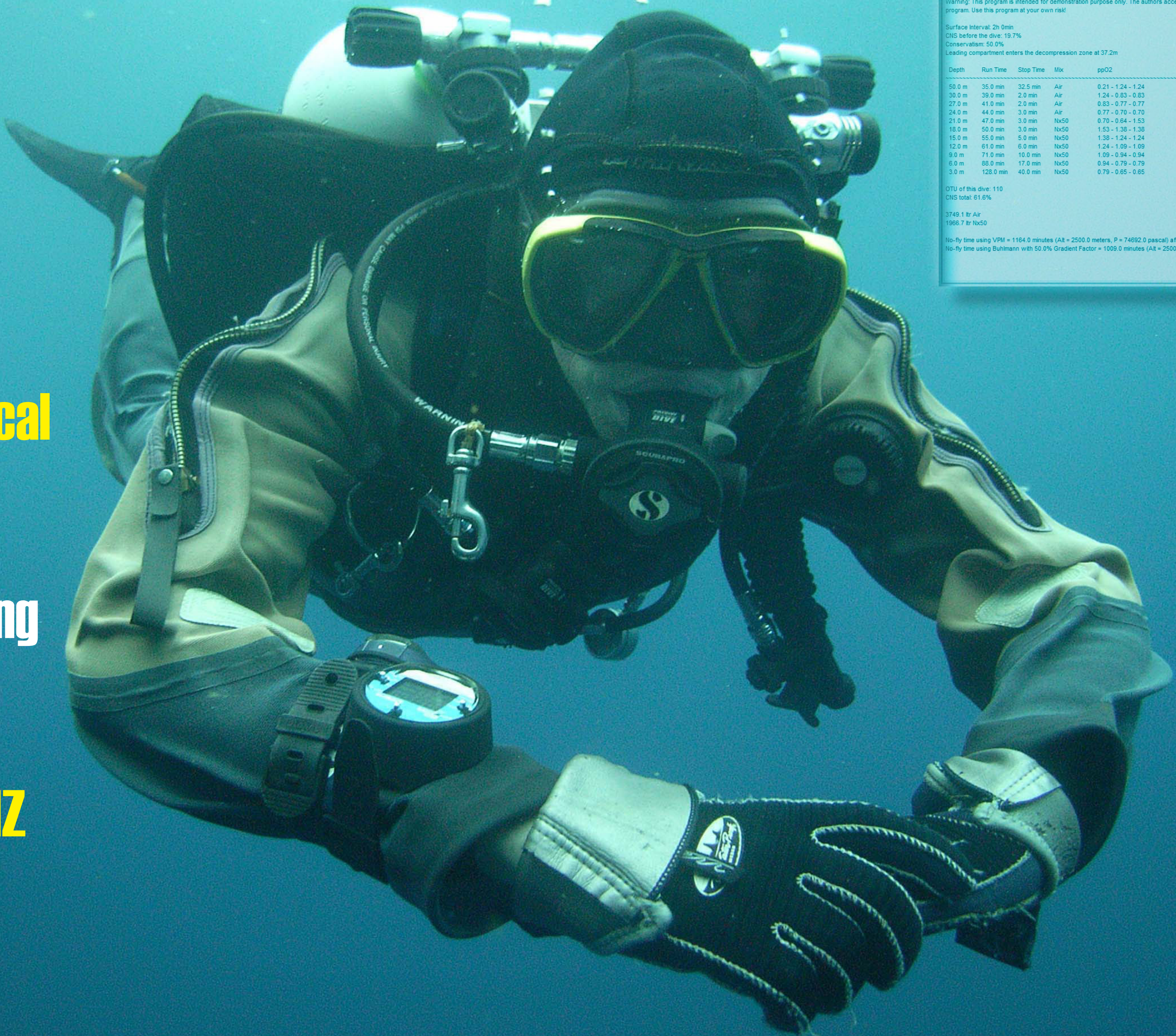
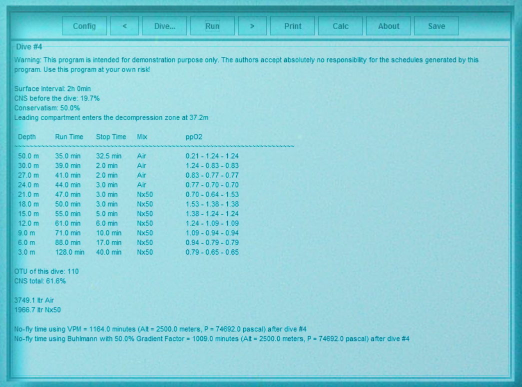
Tech Diving Mag

Research - Development - Exploration





Config | < | Dive... | Run | > | Print | Calc | About | Save

Dive #4

Warning: This program is intended for demonstration purpose only. The authors accept absolutely no responsibility for the schedules generated by this program. Use this program at your own risk!

Surface Interval: 2h 0min
CNS before the dive: 19.7%
Conservatism: 50.0%
Leading compartment enters the decompression zone at 37.2m

Depth	Run Time	Stop Time	Mix	ppO2
50.0 m	35.0 min	32.5 min	Air	0.21 - 1.24 - 1.24
30.0 m	39.0 min	2.0 min	Air	1.24 - 0.83 - 0.83
27.0 m	41.0 min	2.0 min	Air	0.83 - 0.77 - 0.77
24.0 m	44.0 min	3.0 min	Air	0.77 - 0.70 - 0.70
21.0 m	47.0 min	3.0 min	Nx50	0.70 - 0.64 - 1.53
18.0 m	50.0 min	3.0 min	Nx50	1.53 - 1.38 - 1.38
15.0 m	55.0 min	5.0 min	Nx50	1.38 - 1.24 - 1.24
12.0 m	61.0 min	6.0 min	Nx50	1.24 - 1.09 - 1.09
9.0 m	71.0 min	10.0 min	Nx50	1.09 - 0.94 - 0.94
6.0 m	88.0 min	17.0 min	Nx50	0.94 - 0.79 - 0.79
3.0 m	128.0 min	40.0 min	Nx50	0.79 - 0.65 - 0.65

OTU of this dive: 110
CNS total: 61.6%

3749.1 ltr Air
1966.7 ltr Nx50

No-fly time using VPM = 1164.0 minutes (Alt = 2500.0 meters, P = 74692.0 pascal) after dive #4
No-fly time using Buhlmann with 50.0% Gradient Factor = 1009.0 minutes (Alt = 2500.0 meters, P = 74692.0 pascal) after dive #4

Some perspective on technical diving

Accelerating no-fly time using surface oxygen

Exploring a historic site in NZ

Team gas planning

History of deep diving

Issue 1 – December 2010

Contents

Editorial

Welcome to this inaugural issue of Tech Diving Mag.

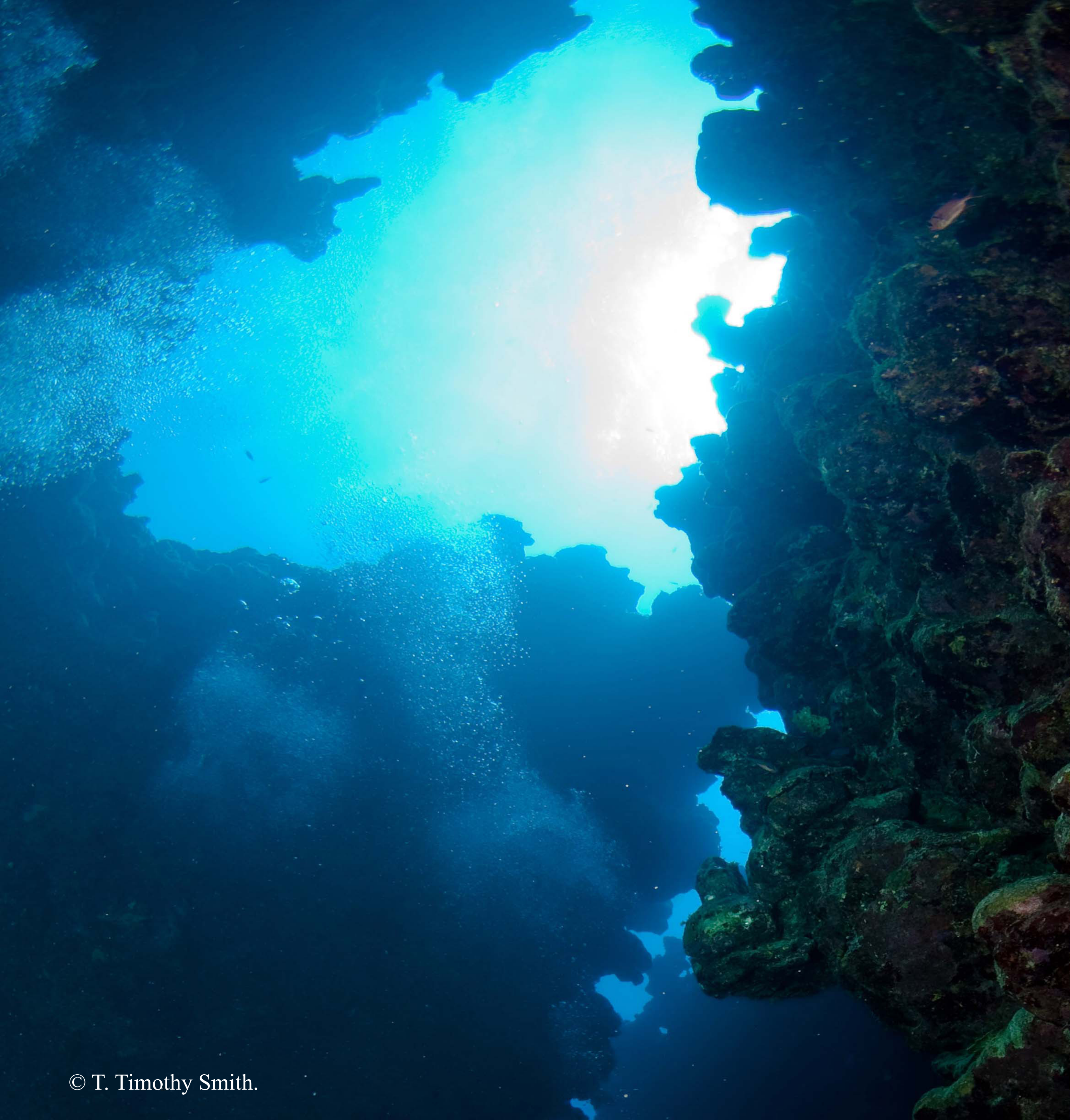
Available free, Tech Diving Mag will be covering a whole raft of subjects for technical divers, but will not try to please everyone and satisfy nobody. As you see, the motto is “Research - Development - Exploration”. Finding quality articles in these disciplines is not easy, but let’s keep our fingers crossed.

I have been fortunate to receive contributions from experienced hardcore divers who are extremely knowledgeable in all aspects of technical diving from deep wreck penetration to CCR and cave exploration. The contributors for the first issue are world renowned industry professional Bret Gilliam and technical instructor and explorer Andy Connor. Read their full bio at www.techdivingmag.com.

Tech Diving Mag will be published every three months. Your contributions, inquiries and feedback are most welcome. This is very much your magazine and I am keen to have your input. If you have any interesting articles, photos or just want to share your views, drop me a line at asser@techdivingmag.com.

Please visit www.techdivingmag.com and subscribe to the newsletter to be notified when new issues are available for download.

Asser Salama
Editor, Tech Diving Mag



© T. Timothy Smith.

SOME PERSPECTIVE ON TECHNICAL DIVING

By Bret Gilliam

I'm pleased to be asked by Asser Salama to contribute to this new magazine dedicated to technical diving. It might be interesting to share some historical perspectives on diving practices that evolved to be known initially as "hi-tech diving" and later simply called "technical" diving.

For many in my age demographic, diving began in the 1950s. I first stuck my head underwater on scuba in Key West back in 1959. My professional career started in January 1971 as a deep diver on film crews filming fast attack submarines for the U.S. Navy during the height of the Cold War era. And although the Navy had well defined programs and protocols for shallow water rebreather missions, deep heliox diving, saturation systems, and explosive ordinance and tactical combat teams, the situations we faced as free-swimming untethered deep divers in virtually bottomless open ocean conditions broke new ground with a lot of the techniques we developed independently. This included accelerated decompression on both oxygen and early nitrox mixes, adaptations to equipment including transitioning to what was then non-standard high performance single hose regulators, buoyancy devices with improvised inflators, new filming methods, and exceptionally deep work on air (400 fsw) before we switched to helium mixes.

When I finished my diving work for the Navy later that year, I went immediately into commercial diving and underwater explosive blasting projects followed later by projects for scientific missions including NOAA and privately funded saturation habitats. By the time I decided to get involved in sport diving in 1972, I was finally introduced to other unique individuals who had been experimenting with similar methodology to advance their wreck and cave diving interests. These folks included pioneers like Sheck Exley, Tom Mount, Hal Watts, Dr. Bob Dill, George Benjamin, Al Giddings, Peter Gimble, Paul Tzimoulis, Jack McKenney, Bob Hollis, Frank Martz and others.

In those days, sport diving was strictly a shallow water (above 100 feet typically) focus for about 90% of the participants and their instructors. The existing training agencies had limited manuals and absolutely no interest in decompression, alternative gas mixes, cave diving, penetration wreck exploration, or deeper diving. So a lot of what the handful of us were doing was limited to a very small cadre of extremely well experienced divers that came from military, commercial or science diving backgrounds. We applied existing methods and expanded the protocols to fit our work projects, explorations, or filming contracts.

Those who did conduct the types of dives that we routinely executed four decades ago all had undertaken rather "in depth" independent study in applicable topics of physics, physiology, equipment engineering, emergency medical contingencies including in-water recompression and operation of field chambers. In short, we used every possible application of available technologies to allow our expanded diving universe with an acceptable level of risk. Even then, there were instances of serious decompression sickness, fatalities, or simply cases where people disappeared and were never found. At times, it could be very sobering. But we shared a common passion to push the technology forward as a means to exploration, science, and lucrative contract assignments.

And up until about 1980, this small cadre of divers existed in something of a parallel universe to the growing sport diving community. There was little controversy about what we did since our ranks had a tendency to "exclude" others rather than widen our circle. Usually someone that was granted access to our dive teams or shared techniques was vetted by a colleague before gaining access to what we were up to and so the community was very close and somewhat "peer reviewed". Meanwhile most of us also had crossover mainstream interests in diving that coexisted with our niche work that was far more challenging and dangerous.

It was a fairly closed society that carefully chose who we considered as peers worthy of inclusion into our circle as we cautiously shared our evolving innovations. Primarily, we shared the same concerns: that less qualified and inexperienced divers would attempt dives beyond their capabilities and get hurt or killed. And frankly, we didn't like what we saw in a lot of the "cowboy" approaches some were taking that resulted in disasters. We wanted nothing to do with these elements that seemed to be killing themselves off with regularity from obviously predictable errors of procedures, equipment, and outright lack of experience. They scared us… and we weren't scared of anything. But these few were giving real explorers a proverbial black eye.

By the beginning of the 1980s, the press and the industry became more aware of these professional groups and generally accepted the deep cave, wreck, and other explorations as exciting and newsworthy. Later in the 1980s, a series of inopportune deaths by some divers who grossly exceeded their expertise and capabilities raised alarms. These events tended to center on some cave events and particularly in the North Atlantic wreck community who seemed to practice their own form of "diving Darwinism" every time a group went out to the ***Andrea Doria*** or other wrecks and managed to get lost inside or simply run out of air due to inherently bad diving practices and a bewildering lack of preparation with improper equipment and woefully lacking support systems.

Finally, at the urging of responsible other professionals like physiologist and algorithm computer modeler Dr. Bill Hamilton, many of us began to speak out and offer cautions as well as delineating guidelines for more responsible practices. In many cases, our input could be summed up as, "If you can't afford to do this type of diving the right way, then stay out of it." An analysis of many fatalities revealed a simple lack of budget to afford the right gases and equipment and sometimes a total lack of any real training or prior experience. In short, a few sensational and well-publicized deaths were giving exploration an underserved bad name.

That's when guys like Exley, Mount, Wes Skiles, Rob Palmer, Jim Bowden, Parker Turner, Lamar Hires, Martyn Farr, Jim King, Bill Stone, and others in the cave community began to come public with training recommendations and operations protocols more formally. Simultaneously, others like Richard Pyle, Joe Odom, Billy Deans, and myself began to present on deep diving and field accident management. In 1988, Dick Rutkowski, the ex-Deputy Director of NOAA's diving program, founded IAND to offer the first program in nitrox training for the regular public. Dr. Morgan Wells, NOAA's Diving Director, also lent his support and awareness began to grow.

In 1991, Mount, Deans and I joined with Rutkowski to expand his original concept of "The Int'l Ass'n of Nitrox Diving" (IAND) to now be "The Int'l Ass'n of Nitrox & Technical Diving" (IANTD). The four of us partnered to create the first all encompassing technical training agency. And we settled on "technical diving" as the best name for this niche abandoning the "high-tech" term that had been attached by some members of the press. In 1994, I departed to expand and create a separate training agency I called Technical Diving International or simply TDI. This company would go on to become the dominant training entity and grow to a multi-national, multi-million dollar corporation that still is the largest of its kind in the world. I sold the company after a decade in 2004 and it still continues its growth and expansion.

None of this early innovation and introduction of new techniques was easy. Widespread criticism came from a small group of ultra-conservatives who wanted to outlaw all breathing mixes except air, all dives deeper than 130 feet, ban decompression, ban diving computers, outlaw rebreathers, and actually tried to enact laws in some areas to stop any divers from pursuing such interests. Of course, their inane efforts failed but it was a struggle to bring the truth forward and most of the 1990s was spent getting the proper information out and letting the diving public make an informed choice.

All this became mainstream and fueled incredible growth in diving's gross national product leaving the naysayers and critics by the wayside… but it was not without harsh words, confrontation, and bitter acrimony at times. But as Dick Rutkowski always noted, "Science Always Overcomes Bullshit!"

He was both right and clairvoyant. A fundamental "sea change" had hit the diving industry and technical diving was going to lead the technology into places previously unimaginable.

My next essay will chronicle the controversies of the 1990s and how the technical community overcame the lunatic conservatives and their private hidden agendas. It's a fascinating and revealing story from an inside perspective as one who was directly involved as a principal spokesperson to the media and the old school industry.

Until then you may enjoy my companion piece that is the first chapter of my best selling book ***Deep Diving: An Advanced Guide to Physiology, Procedures & Systems***. I've included the opening chapter that chronicles the history of deep diving with all its tragedies and triumphs. The book was originally released in its first edition in 1991 and I expanded it for a second edition in 1995. It went on to sell over 100,000 copies in seven languages.

There's some good history here about the pioneers who stuck themselves way out on the edge of the envelope. Some came back… and others didn't. There are valuable lessons to be learned. Enjoy.

Bret Gilliam
President
OCEAN TECH
Email: bretgilliam@gmail.com

Bret Gilliam was one of the first to dive Sinai, dating back to 1973.

ACCELERATING NO-FLY TIME USING SURFACE OXYGEN

By Asser Salama

First of all, I want to make my lawyer happy. This article is discussing some aspects of the decompression theory, which is experimental in nature and can only be said to be an approximation of the physiological effects of diving on the human body. Any enclosed protocols and/or calculations are for illustration purposes only and are aiming at neither calculating nor accelerating no-fly times. The discussed decompression schedules have not been subject to any validation whatsoever. **The author of this article will not be held accountable for any injury caused as a result of applying any of the procedures mentioned hereunder.**

© Andy Connor.

Minimum no-fly time

Divers always look forward to their vacation, and they want to make the most out of it by squeezing in more dives. That's why they frequently ask whether it's possible to safely minimize their no-fly time.

A flying-after-diving workshop has been conducted at DAN in May 2002. The recommendations were as follows:

- For a single no-decompression dive, a minimum pre-flight surface interval of 12 hours is suggested.
- For multiple dives per day or multiple days of diving, a minimum pre-flight surface interval of 18 hours is suggested.
- For dives requiring decompression stops, there is little experimental or published evidence on which to base a recommendation. A pre-flight surface interval substantially longer than 18 hours appears prudent.

All recommendations assume air dives followed by flights at cabin altitudes of 2,000 to 8,000 feet (610 to 2,438 meters) for divers who do not have symptoms of decompression sickness (DCS).

For safety, dive operators usually advise a minimum pre-flight surface interval of 24 hours for both recreational and technical dives. Several dive computer brands recommend the same.

An idea I have in mind is; why don't we use surface oxygen and possibly rich mixes in the shallows to accelerate the recommended surface interval? At the end of the day, this surface interval is nothing but a mandatory stop using air for de-saturation at one atmospheric pressure (on surface) for 24 hours. Our aim is to be "clear" enough to reach an altitude of 8,000 feet (2,438 meters), which is the cabin pressure of commercial airliners. Will using pure oxygen instead of air reduce this surface interval? And if it will, how can we calculate the time saved?

Personal practice of experienced technical divers

Since that's way "technical" for recreational divers, I thought about consulting some of the world's most experienced technical diving instructors. My questions were as follows:

Do you use surface O2 to accelerate no-fly time? If you do, since when and what are the procedures involved? Then based on the empirical data you collected, did you come up with a "table" to follow? If you did, is that available for publishing?

Are the incident records clear?

Do you think that applying a mathematical model – like VPM-B for instance – to substitute the normal air "stop" on surface with a shorter O2 stop applicable?

One thing I'd like to point out is that the positions and statements of the industry professionals listed hereunder are not necessarily those of mine. Their opinions are solely theirs and were quoted as is. These opinions might contain misconceptions.

Bret Gilliam is a technical diving pioneer. He is most famous as the founder of TDI, the largest technical diver training organization in the world. Gilliam logged more than 18,000 dives worldwide since he started diving in 1958, including military and commercial projects. He is former IANTD board member, former president of International Training (TDI, SDI and ERDI), ex-Chairman of the Board of Directors of NAUI International and former CEO of Uwatec USA.

"We began using protocols of surface O2 breathing to reduce time to fly as far back as the early 1970s; very simple procedures. We started to use surface oxygen breathing to allow us to get on planes faster to get out of some areas the same day that we did some diving in the morning. Our protocol was to cut four hours off the no-fly time for every one hour on surface 100% O2 via mask. It's pretty simple when you think about it. Normal atmospheric air is 21% oxygen. Increase your breathing intake to 100% O2 and you gain a 400% advantage. Plus it accelerates inert gas removal even beyond that initially and then begins to taper off exponentially. But we could easily do a couple of long dives before noon, breathe O2 for an hour and fly out later that evening. No problems ever."

"This all began back in the days of dive tables when the basic Haldanean model that the U.S. Navy used was standard practice. There were no personal computers and no dive computers. All dive profiles were "square" except for those of us that used the SOS/Scubapro Decompression Meter. (By the way, those devices worked fine for no-deco multi-level diving. Just never let it go into deco or you would be hanging forever.)"

"Today, virtually decompression algorithms incorporated into dive computers are far more conservative than the Navy model so the surface O2 breathing protocols are probably even more applicable."

"It's all about the priority of your travel and what level of "risk tolerance" you are willing to accept. I have never subscribed to the "24-hour sit down rule" before flying. It just doesn't make sense and most informed professionals chose other "rules" a long time ago."

"There are literally scores of algorithms that can be applied to a mathematical model to expedite inert gas outflow at the surface. It both relieves any sub-clinical decompression stress but also allows shorter intervals before flying. Remember: most commercial aircraft have cabin pressures of about 8,000 feet (2,438 meters). That's not a huge differential."

"What works for me and my diving partners may not work for all. But I'm 59 and have been doing this now for nearly four decades professionally. We've never had an incident."

Steve Lewis is an instructor trainer with TDI since its formation in 1994. Lewis served as a member of its Training Advisory Panel until 2005, when he became director of product development for International Training. He now serves as the marketing and communications director for International Training (TDI, SDI and ERDI).

"I am aware of empirical data… been doing it for almost 20 years. Most extreme case was a three-hour dive in Eagle's Nest – 30 minutes of surface oxygen immediately post dive (about 19:45), 15 minutes in the morning and on a flight at 08:00. Not a niggle."

"Several years ago we had only rudimentary tables and little hard data and no customizable decompression software. Everything we did was seat of the pants. We would work off what was then the general guideline of 12 hours no-fly time and we would surface breathe pure oxygen via a demand mask. For every minute spent on the mask, we would assume three to four minutes of no-fly time had evaporated. Essentially, an hour on the mask immediately post dive meant that our no-fly time was now 8 hours (three hour acceleration) or seven hours (four hour acceleration). We rarely spent more than an hour on the mask at a time because it is so uncomfortable. However, on a couple of occasions, I wore a mask for up to three hours following deep Trimix dives and flew immediately. Well there was the screwing around at the airport for an hour or so, but you get the picture. We never had any issues with niggles or bends."

"I do not know of any incidents of divers flying higher than 6,500 feet (1,980 meters) in unpressurized aircrafts post dive, and do not have any figures or stories to tell of people getting bent flying within 12 hours when they have used oxygen saturation therapy."

"These days I am more circumspect regarding NOAA 24 hour CNS limits, but I still use the old numbers 3:1/4:1 ratio. In addition, I spend longer than VPM calls for at 4 meters (13 feet) breathing pure oxygen or an 85/15 Heliox if a flight is in my immediate future. For example, if the table calls for a total of 35 minutes decompressing at 6 and 3 meters (20 and 10 feet), I will do the required 6 meter (20 feet) stop and then spend 1.5 times the total time at 4 or 5 meters (13 or 17 feet), notwithstanding my CNS status which always governs my behavior."

"With regard to your question about the tables for timing surface intervals, not sure how you would work it but I'd be interested in the results."

Mark Powell has been instructing since 1994. He is teaching technical diving for several leading agencies at all levels up to and including Advanced Trimix. He is the author of "Deco for Divers", a technical guide which provides a comprehensive overview of the principles underlying decompression theory.

"I have used O2, both in extending deco stops and on the surface to reduce the risk at the end of trips. I would generally add 5 to 10 minutes onto last stop and then surface breath for up to 30 minutes after the last dive. However I have never measured or calculated this, it is more of an ad hoc practice."

Ben Reymenants has a long history in technical diving. He's best known for being the dive medic and chamber operator in Phuket, Thailand. Now he is an instructor trainer with more than one agency. Ben is also a training director with TDI and contributes to course development. He has participated in authoring some of TDI and SDI manuals we see today.

"I don't use surface O2 to accelerate no-fly time. But I use it when I have an extremely heavy dive or when I suffer sub-clinical decompression illness. You could use it to allow divers that have done heavy multiple day diving to jump on a plane within 24 hours. This way you give them peace of mind. Keep into consideration that divers jump on the plane tired and dehydrated, then start drinking alcohol, which increases the risk."

"Even using complex decompression software will not allow you to clean tissues up to a level that critical bubble radius is sufficiently reduced allowing for hypobaric exposure. In the old days you could fetch a ride in the chamber on O2 and then step on a plane in 12 hours."

"Take into consideration that there are other enhancers like rest, surface temperature, personal metabolism and hydration where software has no grip on. I don't see a place for this train of thoughts. Be well aware that we are talking slow tissues off-gassing here. Surface O2 will reduce critical bubble tension in fast tissues, but will also induce peripheral vaso-constriction. At this point it is unknown if this can actually slow down the off-gassing of the slowest tissues."

"The software can only hope for those enhancers and also this exposure is short term, whereas at the surface it is long term. Is the person resting? Running around? Sleeping?"

"I used to accelerate decompression in chambers on pure oxygen, at the surface and at 20 meter (65 foot) depth. A few times I had transient skin bents, just because I was cold during deco."

Brett Hemphill has been cave diving since 1990 and has assisted with exploration in underwater caves in Florida, Missouri, Bahamas and Mexico. He has also designed a holistic side-mount configuration. In late 2006, Brett began working as technical consultant for KISS Rebreathers and is very involved with furthering safety protocols and equipment configurations for cave diving with CCRs.

"There is some merit to the question you are asking concerning possibly expediting possible no-fly times after being in decompression."

"I am sure padding decompression, surface O2 and additional hydration might possibly decrease the onset of decompression sickness brought on by flight in a non-compressed plane but using any collaborative data to promote this venture probably would not be accepted widely."

"Another good example would be a dive I and my friends will be doing in a week or two. Several 300 foot (90 meter) dives within a week. We will continue to increase our bottom time over every other day for three days. Question; with residual nitrogen being present how can we keep from elongating upcoming decompressions without incurring DCS?"

"This is a somewhat relative comparison to the question you are also asking. I will be increasing my 40 foot (12 meter) stop on every subsequent dive in order to optimize the off-gassing of denser tissue compartments that just don't respond as effectively at 20 feet (6 meters) as they would at 40 feet (12 meters). I will not essentially be running higher O2 at this depth but certainly maintain a smooth curve while monitoring my O2 clock, as I believe can be turned back and reset especially at this depth where on-gassing just doesn't occur."

"Ultimately if a person must fly and cannot perform an adequate amount of additional decompression, I am sure that additional O2 and hydration would certainly lessen the possibility of "altitude type DCS" but even Dr. Bruce Wienke, who at this time is still considered to be the most knowledgeable dive gas physicist would never publish or promote any more than what I've possibly suggested. Any possible gains one might achieve couldn't outweigh the equally possible adverse affects."

© T. Timothy Smith.

Research-related point of view

In conclusion, we have some people with clear protocols. Others believe it would help yet can't encapsulate this help in the form of definite procedures. Now let's consult people involved in research.

Gene Hobbs works for Duke University's Human Simulation and Patient Safety Center and Center for Hyperbaric Medicine and

Environmental Physiology. Gene is also a founding board member of The Rubicon Foundation, a research repository including electronic versions of many diving research papers. He is the 2010 DAN/Rolex Diver of the Year.

"There has never been any research on this but I did run some numbers one time. I do know a few folks that do surface O2 for that same reason and they report that they are happy with the procedure. That theory seemed to hold with our current risk models."

"The modern probabilistic decompression models show a reduction in DCS risk from any oxygen breathing prior to an altitude exposure for the profiles I ran. Of course, they also show a reduction from extending the in-water oxygen breathing period as well. We published the abstract showing that O2 breathing with a last stop at 20 feet (6 meters) versus 10 feet (3 meters) does not make much difference on DCS risk but hard to guess if the difference between an in-water extension versus a surface exposure would be significant. I did not run those numbers."

"But if there is enough interest, I could probably talk the Navy into letting me run more numbers through their models. Still not sure it's worth putting the idea in the minds of the general diving public though."

But Gene, why do you think the idea is not worth it? It saves time, which means more dives and accordingly more enjoyment of dive vacations and more profit for the dive operators.

"I am going to ignore the legal ramifications when you start talking about "recommendations" that have no basis in science or in any way could be argued as less conservative. First person to get hurt or first flight that was diverted to facilitate treatment would be ugly."

"What it really comes down to in my mind is acceptable risk and should that level of risk be set by the industry or the individual. Unless there is a reason to change the current level of acceptable risk or even just re-define the current risks, nothing will change. Given the severe lack of funding for decompression research, I doubt anything would come of it unless the Special Warfare (SPECWAR) operators asked for it. That's how the current U.S. Navy flying-after-diving table came to be."

"Fun note: This data set included flights to 25,000 feet (7,620 meters) after dives. The interesting thing here is that a 25,000 foot (7,620 meter) exposure requires and 30 minute oxygen pre-breathe anyway [1]."

"The current recommendations are very conservative based partially on the concerns of a rapid cabin depressurization. I understand the concern but feel it would be useful to take another look at that given the data available. High altitude exposure has its own risk without a dive prior but that probability of DCS given the estimated altitude and short exposure just does not seem that high based on one evidence-based review by NASA [2]. The U.S. Navy has reported 11 Cases of DCS in one case review of 205 cases of "loss of cabin pressure" covering the years 1969 to 1990 [3]. The Canadian Military reviewed "loss of cabin pressure" in transport aircraft and reported no cases of DCS in 47 incidents [4]. Any reduction in time to fly by an O2 breathing period would increase this risk but is that acceptable?"

"A good example of a fun idea that was published but never turned into something more was the article in Advanced Diver a while back on "Benthic Mix Switching" by Glenn H. Taylor. That could theoretically do the exact same thing as your idea since none of the tissue gas loads would be as high as they would on a "traditional" schedule. Nothing has come of it and I seriously doubt it ever would. Again we are back to the lack of funding."

"I can't really say any of the available algorithms have a real advantage over the others. Could be interesting to try this with all of the algorithms but I can't see how I would use/trust it. Until the model could also calculate a flight ascent with a max altitude of 8,000 feet (2,438 meters), any stop time would be a guess at best. Altitude decompression is a very different animal from diving decompression. That's why the Navy and Air Force have different models for each condition."

"Another consideration is that most of the divers I know that are bothered by these guidelines are active divers that are rarely out of the water for more than a couple of days. Their level of acclimatization to decompression could be protective when it comes to the additional decompression stress associated with a flight after a short surface interval. Unfortunately, there is not a good method for determining how long it take for this acclimatization to occur or how long it takes for it to diminish. Divers never talk about "work-up" dives anymore but the physiology is the same now as it has been since Haldane."

"One other thing that has to be considered is repetitive flights after diving. These will also include bubble growth and reduction and changes in the gas dynamics that have never been looked at and the current guidelines fail when it comes to this topic."

Neal Pollock is a Ph.D. degree holder who works as a research director for Divers Alert Network (DAN) and the Center for Hyperbaric Medicine and Environmental Physiology at Duke University's Medical Center.

"Trials were conducted at Duke University in the late 1980s to evaluate the efficacy of surface interval oxygen breathing (SIO2) to reduce decompression stress. We conducted Phase II controlled open water trials in a Florida spring in 1991. We did have good success in extending no-decompression time with 30 minutes of oxygen breathing but the demands of the effort were onerous (maximum of five minutes between surfacing and initiation, aggressive mask management to ensure maximal oxygen fraction breathing and absolute maintenance of rest throughout the breathing period). NOAA had funded the work with an interest in developing time saving operational protocols, but the restrictions on post-dive practice contributed to a subsequent decision to not pursue implementation."

"The effort was proof of concept. SIO2 dive tables were not developed through the effort."

VPM-B/NFT-A - Dive #4

Config | < | Dive... | Run | > | Print | Calc | About | Save

Dive #4

Warning: This program is intended for demonstration purpose only. The authors accept absolutely no responsibility for the schedules generated by this program. Use this program at your own risk!

Surface Interval: 2h 0min
CNS before the dive: 19.7%
Conservatism: 50.0%
Leading compartment enters the decompression zone at 37.2m

Depth	Run Time	Stop Time	Mix	ppO2
50.0 m	35.0 min	32.5 min	Air	0.21 - 1.24 - 1.24
30.0 m	39.0 min	2.0 min	Air	1.24 - 0.83 - 0.83
27.0 m	41.0 min	2.0 min	Air	0.83 - 0.77 - 0.77
24.0 m	44.0 min	3.0 min	Air	0.77 - 0.70 - 0.70
21.0 m	47.0 min	3.0 min	Nx50	0.70 - 0.64 - 1.53
18.0 m	50.0 min	3.0 min	Nx50	1.53 - 1.38 - 1.38
15.0 m	55.0 min	5.0 min	Nx50	1.38 - 1.24 - 1.24
12.0 m	61.0 min	6.0 min	Nx50	1.24 - 1.09 - 1.09
9.0 m	71.0 min	10.0 min	Nx50	1.09 - 0.94 - 0.94
6.0 m	88.0 min	17.0 min	Nx50	0.94 - 0.79 - 0.79
3.0 m	128.0 min	40.0 min	Nx50	0.79 - 0.65 - 0.65

OTU of this dive: 110
CNS total: 61.6%

3749.1 ltr Air
1966.7 ltr Nx50

No-fly time using VPM = 1164.0 minutes (Alt = 2500.0 meters, P = 74692.0 pascal) after dive #4
No-fly time using Buhlmann with 50.0% Gradient Factor = 1009.0 minutes (Alt = 2500.0 meters, P = 74692.0 pascal) after dive #4

Calculating the decompression schedule using VPM-B

The current no-fly times suggested by DAN were not predicted by mathematical algorithms. They are empirical data based on observations and actual occurrences of DCS. The algorithms were then fit around the empirical data. In conclusion, what the algorithms predict is not necessarily what actually happens. However, we will try to use more than one of the existing decompression algorithms and see how it fits around DAN recommendations.

The Varying Permeability Model with Boyle's law compensation (VPM-B) is well known and is used in many PC-based decompression planning programs. Nowadays it is a preferred approach – kind of a standard. VPM-B is a dual phase (bubble) model, which means that it aims at limiting and controlling bubble growth, size and number throughout the ascent for better overall decompression results.

For the reasons mentioned above, I've chosen the VPM-B algorithm to calculate the decompression profiles. The no-fly time will be a further step based on the generated profiles. Although software development is one of my hobbies, I've contacted a professional software developer.

Jurij Zelic has graduated electronics at University of Ljubljana. He is a full time software developer with almost 15 years experience in low level system software programming. He is currently the system software development manager at one of the leading telecom solution providers in Slovenia. Jurij is ANDI Trimix Diver and NACD Intro to Cave Diver. He has kindly agreed to contribute some time and effort to this research.

Jurij has developed a VPM-B program based on Eric Baker's original FORTRAN code. The program employs the sixteen paired compartments (total of 32 compartments; 16 for nitrogen and 16 for helium) of Buhlmann's ZH-L16B model. The optional compartment 1b is put in use. The program has seven levels of conservatism (0 through 6 – 0 to 50%). Conservatism is based around critical radii of inert gases.

Critical volume algorithm is implemented as well. It calculates the total volume of released inert gases in the body and continuously compares it to the critical volume, which is the maximum volume of released inert gases that the body can deal with in a limited period of time. In order to avoid DCS, this total volume should never exceed the critical volume at any time. The produced decompression profiles were compared to those generated by commercial PC-based planning programs to ensure that the program is running flawlessly.

Calculating no-fly time using VPM

The next step is to calculate the no-fly time after a dive or a series of dives. Here we are looking at the flight as just another deco stop. I simulated a busy weekend containing 4 dives over 2 days, each to 50 meter (164 foot) depth, with a bottom time of 35 minutes. The first day includes two dives, the first with a preceding surface interval of more than 48 hours. The surface interval between the first and second dives was only 2 hours. The second day assumes a first dive with a preceding surface interval of 15 hours, followed by a dive after only 2 hours surface interval. Here we are talking about open circuit profiles for salt water diving at sea level (zero altitude). We are assuming maximum level of conservatism (level 6 – 50%).

The reason behind the 50 meter (164 foot) ceiling is to compare the results of diving on air to those of diving on Trimix. Most agencies limit deep air classes to 55 meters (180 feet). The decompression gas was EAN50 starting at 21 meters (70 feet). The calculations were done for two different bottom mixes; air and TMX21/20 (END 35 meters –

115 feet).

As mentioned earlier, commercial, pressurized aircrafts are required to be capable of maintaining a cabin altitude of 8,000 feet (2,438 meters). However, higher cabin altitudes during normal commercial flights were recorded. For the purpose of this article, 8,200 feet (2,500 meters) will be our highest cabin altitude. The plane should be reaching the end altitude in no less than 15 minute time. However, this "ascent rate" has very little to do with the calculations.

It is worth mentioning that there's no need to employ Boyle's law for calculating the no-fly time. Boyle's law compensation is a modification to the original VPM algorithm to recalculate the allowable gradients at each stop instead of using the ones calculated at the first stop. Since the no-fly time is only one "stop", and we do not plan on ascending higher, all what we need for this part is the original VPM algorithm without accounting for Boyle's law compensation.

When diving on air, the no-fly time after the fourth dive was 1,164 minutes (19 hours and 24 minutes).

With all other parameters kept constant, when the maximum depth of the last dive was decreased to 45 meters instead of 50 (148 feet instead of 164), the no-fly time increased to 1,249 minutes. When it was increased to 55 meters (180 feet), the no-fly time became 1,192 minutes.

With all other parameters kept constant, when the bottom time of the last dive was reduced to 30 minutes instead of 35, the no-fly time decreased to 1,123 minutes. When it was decreased further to 25 minutes, the no-fly time decreased further to 1,077 minutes.

When diving on TMX21/20, the no-fly time after the fourth dive was 928 minutes (15 hours and 28 minutes).

With all other parameters kept constant, when the maximum depth of the last dive was decreased to 45 meters instead of 50 (148 feet instead of 164), the no-fly time increased to 996 minutes. When it was increased to 55 meters (180 feet), the no-fly time became 953 minutes.

With all other parameters kept constant, when the bottom time of the last dive was reduced to 30 minutes instead of 35, the no-fly time decreased to 889 minutes. When it was decreased further to 25 minutes, the no-fly time decreased further to 848 minutes.

These are very interesting results! In contrast to what the majority might think, it seems that, when VPM is in action, shallower depths do not necessarily mean less no-fly time. And no, it's not because we're applying VPM rather than VPM-B. This is not the traditional flaw that VPM-B was developed to overcome. Please remember that the decompression schedules were originally generated using VPM-B. VPM is used only to calculate the no-fly time.

On the other hand, shorter dives seem to always contribute to shorter no-fly time.

Calculating no-fly time using Buhlmann's model with Gradient Factors

Since the program already uses the sixteen paired compartments of Buhlmann's ZH-L16B model, it was pretty easy to employ Buhlmann's M-values and apply the algorithm to calculate the no-fly time on top of the dive schedules already calculated using VPM-B algorithm. In contrast to VPM, Buhlmann's model is a traditional dissolved gas model not a dual phase one, which means that it does not track the gas bubbles present in the body. That's why I trimmed the results using a gradient factor. Since it's only one "stop", one gradient factor (rather than high and low) is used. The calculations assume a gradient factor of 50%.

When diving on air, the no-fly time after the fourth dive was 1,009 minutes (16 hours and 49 minutes).

With all other parameters kept constant, when the maximum depth of the last dive was decreased to 45 meters instead of 50 (148 feet instead of 164), the no-fly time decreased to 966 minutes. When it was increased to 55 meters (180 feet), the no-fly time became 1,053 minutes.

With all other parameters kept constant, when the bottom time of the last dive was reduced to 30 minutes instead of 35, the no-fly time decreased to 969 minutes. When it was decreased further to 25 minutes, the no-fly time decreased further to 925 minutes.

When diving on TMX21/20, the no-fly time after the fourth dive was 793 minutes (13 hours and 13 minutes).

With all other parameters kept constant, when the maximum depth of the last dive was decreased to 45 meters instead of 50 (148 feet instead of 164), the no-fly time decreased to 756 minutes. When it was increased to 55 meters (180 feet), the no-fly time became 830 minutes.

With all other parameters kept constant, when the bottom time of the last dive was reduced to 30 minutes instead of 35, the no-fly time decreased to 757 minutes. When it was decreased further to 25 minutes, the no-fly time decreased further to 719 minutes.

It seems that, when applying Buhlmann's algorithm trimmed with a Gradient Factor, no-fly time is directly proportional to depth. It is also directly proportional to bottom time.

Accelerating no-fly time using rich mixes

Well, it's just another mandatory stop. A rich mix will increase the inert gas gradient and accordingly will accelerate the decompression. In addition, breathing a rich mix indicates breathing a high partial pressure of oxygen, which increases the drop in partial pressure between arterial and venous systems, leading to reduced bubbling. And reduced bubbling is reduced probability of DCS occurrence. Moreover, breathing a rich mix means breathing a reduced level of inert gas. This helps control the bubble volume. Controlling the bubble volume means that we can fly earlier without permitting the total volume of released inert gases to exceed the critical volume.

First I want to measure the effect of adding several minutes of rich mix breathing to the last stop (3 meters – 10 feet) of the last dive. When diving on air, I added 15 minutes on top of the original stop time. The mix is still EAN50. The no-fly time became 1,144 minutes (instead of 1,164) when applying VPM, and 988 minutes (instead of 1,009) when applying Buhlmann's algorithm with 50% Gradient Factor. The time saved using VPM is 1,164 – 1,144 – 15 = 5 minutes, and 1,009 – 988 – 15 = 6 minutes using Buhlmann. The time saved is relatively small, but take into consideration that the mix (EAN50) is not that rich. In conclusion, adding several minutes of rich mix breathing to the last stop seems to help accelerate the no-fly time.

Now back to the original settings. When breathing pure oxygen on the surface for 60 minutes directly after surfacing (0 minutes surface interval), the no-fly time became as follows:

Case 1: Diving air and using VPM: 959 minutes.
Case 2: Diving air and using Buhlmann's algorithm with 50% Gradient Factor: 804 minutes.
Case 3: Diving TMX21/20 and using VPM: 714 minutes.
Case 4: Diving TMX21/20 and using Buhlmann's algorithm with 50% Gradient Factor: 585 minutes.

The time saving is as follows:

Case 1: 1,164 – 959 – 60 = 145 minutes.
Case 2: 1,009 – 804 – 60 = 145 minutes.
Case 3: 928 – 714 – 60 = 154 minutes.
Case 4: 793 – 585 – 60 = 148 minutes.

Another quite interesting result! For air dives, whether using VPM or Buhlmann, the time saving is the same.

The saving ratio is 145 / 60 = 2.42 for air dives. For TMX21/20 using VPM, the ratio is 154 / 60 = 2.57.

Now let's see the effect of timing. Let's assume that we will wait for 2 hours before breathing the pure oxygen. The duration is still 60 minutes. The no-fly time became as follows:

Case 5: Diving air and using VPM: 817 minutes.
Case 6: Diving air and using Buhlmann's algorithm with 50% Gradient Factor: 662 minutes.
Case 7: Diving TMX21/20 and using VPM: 571 minutes.
Case 8: Diving TMX21/20 and using Buhlmann's algorithm with 50% Gradient Factor: 443 minutes.

The time saving is as follows:

Case 5: 1,164 – 817 – 60 – 120 = 167 minutes.
Case 6: 1,009 – 662 – 60 – 120 = 167 minutes.
Case 7: 928 – 571 – 60 – 120 = 177 minutes.
Case 8: 793 – 443 – 60 – 120 = 170 minutes.

The saving ratio is 167 / 60 = 2.78 for air dives. For TMX21/20 using VPM, the ratio is 177 / 60 = 2.95.

But there's one more interesting result! Having a "normal" air surface interval before breathing oxygen seems to enhance the time saving. Fine, let's assume that we will wait for 6 hours before breathing the pure oxygen. The duration is still 60 minutes. The no-fly time became as follows:

Case 9: Diving air and using VPM: 521 minutes.
Case 10: Diving air and using Buhlmann's algorithm with 50% Gradient Factor: 366 minutes.
Case 11: Diving TMX21/20 and using VPM: 275 minutes.
Case 12: Diving TMX21/20 and using Buhlmann's algorithm with 50% Gradient Factor: 150 minutes.

The time saving is as follows:

Case 9: 1,164 – 521 – 60 – 360 = 223 minutes.
Case 10: 1,009 – 366 – 60 – 360 = 223 minutes.
Case 11: 928 – 275 – 60 – 360 = 233 minutes.
Case 12: 793 – 150 – 60 – 360 = 223 minutes.

The saving ratio is 223 / 60 = 3.72 for air dives. For TMX21/20 using VPM, the ratio is 233 / 60 = 3.88.

These results not only confirm the interesting observation of time saving using different arithmetic models, but also help deny the claim that breathing surface oxygen directly after surfacing results in better no-fly time saving.

Findings

As per the examples we've gone through, it seems that the no-fly time is substantially less when Trimix diving is considered rather than air diving. However, the time saving once surface oxygen breathing is engaged is almost the same.

It also seems that, when VPM is in action, shallower depths do not necessarily mean less no-fly time. However, shorter dives seem to always contribute to shorter no-fly time.

Adding several minutes of rich mix breathing to the last stop seems to help accelerate the no-fly time.

For air dives, whether using VPM or Buhlmann, the no-fly time saving using surface oxygen breathing seems to be always the same. For Trimix dives, it seems to be very close.

Having a "normal" air surface interval before breathing a rich mix on the surface seems to enhance the no-fly time saving.

A better approach?

Well, I admit I was sidetracked. Although it's a mandatory step to come up with conclusions, calculating the no-fly time was not my objective. Matching the recommended minimum no-fly time with the program's output is neither an easy nor a risk-free task. As shown above, we are considering a degree of conservatism of 50% on VPM yet the resulting no-fly time is only 19 hours 24 minutes for the air dives and 15 hours and 28 minutes for the TMX21/20 dives. Decreasing the level of conservatism to 20%, which is an acceptable degree of conservatism by many divers, results in a no-fly time of 10 hours 57 minutes for air dives and 8 hours 39 minutes for the TMX21/20 dives! Now that's nowhere close to DAN's recommendations.

So since our objective is to calculate the no-fly time's saving when the divers engage in oxygen breathing on the surface, another idea just flashed into my mind. Why don't we deal with the no-fly time as an input? In other words, the diver inputs the no-fly time he would normally follow without taking into consideration any surface oxygen breathing. The program calculates the gradient factor accordingly. For instance, if I would have done these dives, I would have considered a pre-flight surface interval of at least 24 hours. Now we enter the 24 hours to the program as input, and ask for the corresponding gradient factor as output.

But is it possible to do the same for VPM; to calculate the degree of conservatism accordingly? The answer is no. Conservatism of VPM and VPM-B is based around the critical radii of inert gases, meaning that the critical radii of inert gases increase according to the selected level of conservatism. "Playing" with the degree of conservatism would subject the accuracy of the decompression profile to all sorts of risk. That's why we will deal with it as a pure dissolved gas problem.

The accuracy of calculating the gradient factor is 1%, which means that the no-fly time might increase (but not decrease) a few minutes.

With a conservatism level of 20% and an input no-fly time of 24 hours, the corresponding gradient factors were as follows:

For air dives: 33% (the calculated no-fly time is 1,457 minutes – 24 hours and 17 minutes).

For TMX21/20 dives: 25% (the calculated no-fly time is 1,477 minutes – 24 hours and 37 minutes).

When breathing pure oxygen on the surface for 60 minutes directly after surfacing (0 minutes surface interval), the no-fly time became as follows:

For air dives: 1,253 minutes.
For TMX21/20 dives: 1,232 minutes.

The time saving is as follows:

For air dives: 1,457 – 1,253 – 60 = 144 minutes. The saving ratio is 144 / 60 = 2.4.
For TMX21/20 dives: 1,477 – 1,232 – 60 = 185 minutes. The saving ratio is 185 / 3.08.

When breathing pure oxygen on the surface for 60 minutes 2 hours after surfacing, the no-fly time became as follows:

For air dives: 1,112 minutes.
For TMX21/20 dives: 1,083 minutes.

The time saving is as follows:

For air dives: 1,457 – 1,112 – 60 – 120 = 165 minutes. The saving ratio is 165 / 60 = 2.75.
For TMX21/20 dives: 1,477 – 1,083 – 60 – 120 = 214 minutes. The saving ratio is 214 / 60 = 3.57.

When breathing pure oxygen on the surface for 60 minutes 6 hours after surfacing, the no-fly time became as follows:

For air dives: 816 minutes.
For TMX21/20 dives: 772 minutes.

The time saving is as follows:

For air dives: 1,457 – 816 – 60 – 360 = 221 minutes. The saving ratio is 221 / 60 = 3.68.
For TMX21/20 dives: 1,477 – 772 – 60 – 120 = 285 minutes. The saving ratio is 285 / 60 = 4.75.

Findings revisited

A very interesting finding is that the time savings when air dives are involved are always very close, regardless the model, level of conservatism or gradient factor incorporated.

Still, having a "normal" air surface interval before breathing a rich mix on the surface seems to enhance the no-fly time saving. It's obvious that the gradient for inert gas elimination is steepest immediately post-dive. That's why I think breathing oxygen is a substantial aid at this point. But it seems that the models think that the gradient is high enough immediately after surfacing so "giving it a hand" at this point will not have the same effect as giving it the very same hand when it's substantially less. To verify this point, let's consult a decompression expert.

Michael Powell is a Ph.D. degree holder who has retired but formerly worked for NASA at the Johnson Space Center, TX, as a research biophysicist in the Bioastronautics Division. Most of his "dives" have been associated with research or medical therapy in a hyperbaric or hypobaric chamber. He has developed a scale for grading bubbles using Doppler technology. He has also participated in testing the M-values used for PADI Recreational Dive Planner (RDP). Dr. Powell is currently writing a book on the physiology of decompression.

"Data is the best way to calculate anything related to diving and decompression. Sufficient data, as you know, are not always available."

"Algorithms are calculation methods and are not true physiological models. While "model" is a term used in barophysiology, there do not exist any actual, valid models that agree with physiology in most aspects."

"Bubble size is controlled, but bubble number can change (apparently) with exercise (any physical activity, such as hauling tanks, dive gear and suitcases). Nuclei concentration is not included in any model. Although number is stated as being controlled in the VPM model, I do not believe that variable nuclei number is in the VPM algorithm – except where nuclei replacement is calculated in Dr. Wienke's model."

"Oxygen breathing at the surface should definitely increase safety. Your model shows some improvement but the decreased fly time is not improved as one might guess. We used long oxygen breathing following dives in the Neutral Buoyancy Lab (testing EVA procedures). This was to allow the astronauts to fry back to their home base with a shorter surface interval. It was found to be very successful if the surface interval was originally at least 10 hours. As long as the dive-fly interval is at least 12 hours, the diver will probably be OK. Shorter surface intervals are very sensitive to the diver's activity (hauling gear, suitcases, etc…) that can generate microbubbles in an unpredictable manner."

Conclusion

Finally, as Dr. Neal Pollock says, the presentation of these computations should not come across as implying that models describe "truth". This is unlikely to be the case. The output of any model should be viewed with a high level of caution. Actually when the degree of conservatism and/or the deco mix change, the numbers change substantially.

Asser Salama
Technical Diving Instructor
asser@red-sea-shadow.com

References

[1] Pollock NW, Natoli MJ, Gerth WA, Thalmann ED and Vann RD. Risk of decompression sickness during exposure to high cabin altitude after diving. Aviat Space Environ Med. 2003 Nov; 74(11):1163-8. PMID: 14620473

[2] Robinson RR, Dervay JP and Conkin J. An Evidenced-Based Approach for Estimating Decompression Sickness Risk in Aircraft Operations. NASA/TM—1999–209374

[3] Bason R and Yacavone DW. Loss of cabin pressurization in U.S. Naval aircraft: 1969-90. Aviat Space Environ Med. 1992 May; 63(5):341-5. PubMed ID: 1599378

[4] Brooks CJ. Loss of cabin pressure in Canadian Forces transport aircraft, 1963-1984. Aviat Space Environ Med. 1987 Mar; 58(3):268-75. PubMed ID: 3579812

General references

- Powell, M. *Deco for Divers*. Chapter 6: Deep Stops and Bubble Models. Aqua Press Ltd, 2009.
- Baker, E.C. 1998. *Understanding M-values*.
- Baker, E.C. 1998. *Clearing Up The Confusion About "Deep Stops"*.
- Kaluza M. 2005. *VPM – The Inner Workings*.

EXPLORING A HISTORIC SITE IN NZ

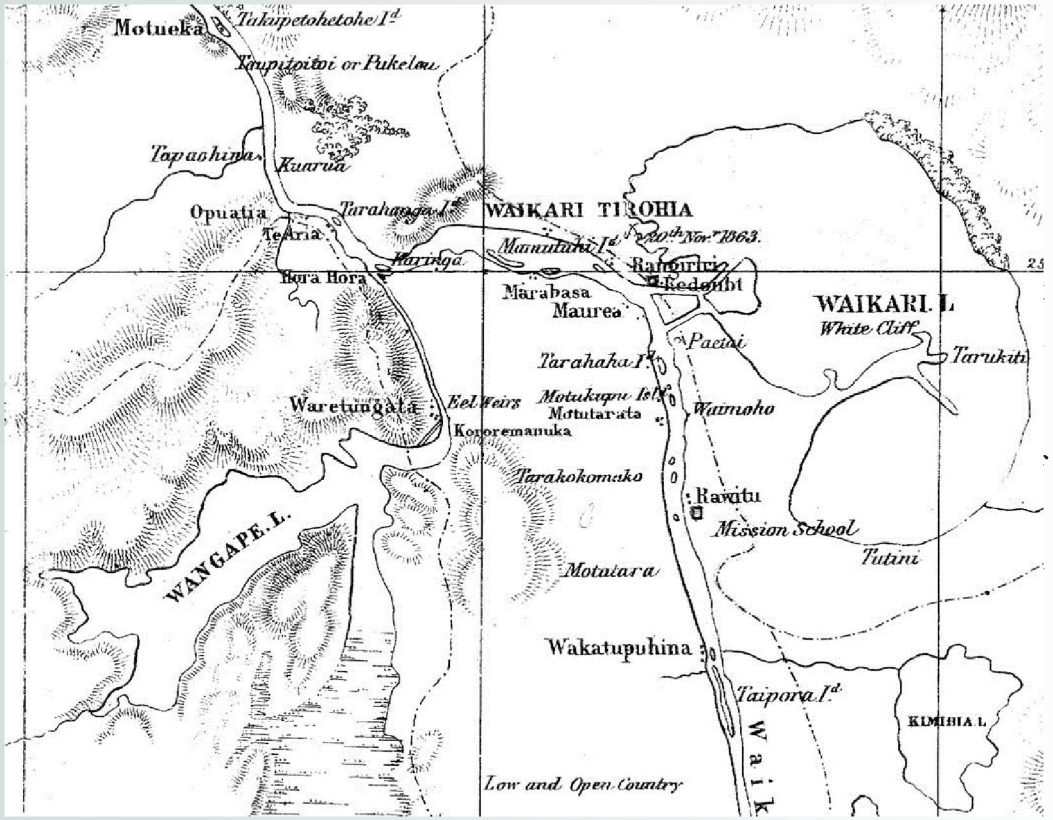
By Andy Connor

One of the things I really love about wreck diving is that each time you dive a wreck, you get a connection to its history. From every aspect of the dive, research the wreck to gliding through its superstructure gives me a feeling of the events that led up to its sinking and what has happened since. I never thought I'd get that same feeling, until a friend mentioned in passing that there was an old power station in Lake Karapiro that became submerged when the lake was created. The idea became a seed that germinated over time, I had to dive this. The whole idea of a technical expedition just a couple of hours from home was a great opportunity.

But where to start? Lake Karapiro is huge, what are the chances of finding the site in a lake that is 11km long? I started digging around on the internet, finding the odd clue here and there would eventually help us to find the site – but the more I found, the more intriguing the history of the power station became, and the stronger the desire to dive it became.

Horahora power station was built in 1910, it was New Zealand's first hydro-electric power station and was built by the Waihi gold mining company to provide power for mining operations at Waihi, about 80 km away. Construction took three years, continuing through the Waihi miners' strike despite attempts to involve the Horahora construction workers in the strike action. When the power station opened in October 1913 it was the largest generating plant in the country. The magnitude of the construction effort only became apparent when I found that the Waikato River was diverted to create the reservoir – a piece of information that became key in finding of the site. Comparing maps from the late 1800s to today shows just how much the river was diverted, and the maps helped narrow down our search to around about half a kilometer of the lake.

More research unearthed more history, the power station was bought by the government in 1919 and it began to supply Cambridge, Hamilton and surrounding farming districts. In 1926 the power station was upgraded, increasing capacity to 10.3 MW… but it had passed its middle age and the end was coming for Horahora. Growing power shortages produced larger power stations on the Waikato, until finally in 1947 Lake Karapiro was created to store water for the Karapiro Power Station, the last of the eight hydroelectric power stations on the Waikato River, and in its creation Horahora power station was swallowed forever. The lake began to fill on March 4, 1947, and the process took about a week. Many people flocked to watch as Horahora powerhouse and surroundings gradually disappeared and the riverscape changed forever. Because of the shortage of power, the station was left running as the lake filled, with turbines thrashing as the water level



rose. Horahora power station had eight generators and generator No7 was unable to be shut down as it was covered by water, giving rise to the legend that Horahora refused to die.

How can any diver find this story, and the promise of the dive not compelling? Old photos show the turbines in place, and buildings on the old riverbank that housed 40 people. This surely has to be dived. The final piece in the puzzle fell into place, after information from the Waikato Historical Society came through by email – "The whole of the power station complex is submerged beneath Lake Karapiro. The only visible remains are the top of the ramp for heavy equipment and the steps leading down to the power house - these are located on the true right bank of the Lake just below Finlay Park Adventure Camp".

Witteam, picking the day and doing the dive. Or so we thought.

With a team assembled we starting thinking about the logistics, but not exactly knowing what to expect, we loaded up the cars with twinsets, lights, oxygen deco tanks and reels. The only thing we knew for sure was the maximum depth of the lake, around 32m. The promise of diving a flooded power station was too great for us to do this by halves. If it was good, it was going to be a long dive! Meeting at our rendezvous point, we started scouring the banks of the lake looking for the steps that we knew were somewhere nearby – but access was barred by a gorse and bramble hedge. Wandering around for an hour, we found nothing. But thankfully, when being told off for trespassing one of the locals gave us the precise location we were looking for – we were about half a kilometer away. From the road, it's a good 1.5km walk over fields to reach the site of the steps. We decided that the six of us would schlep two sets of gear from the car first and one pair of divers would do an initial dive and report back before bringing the rest of the gear over.

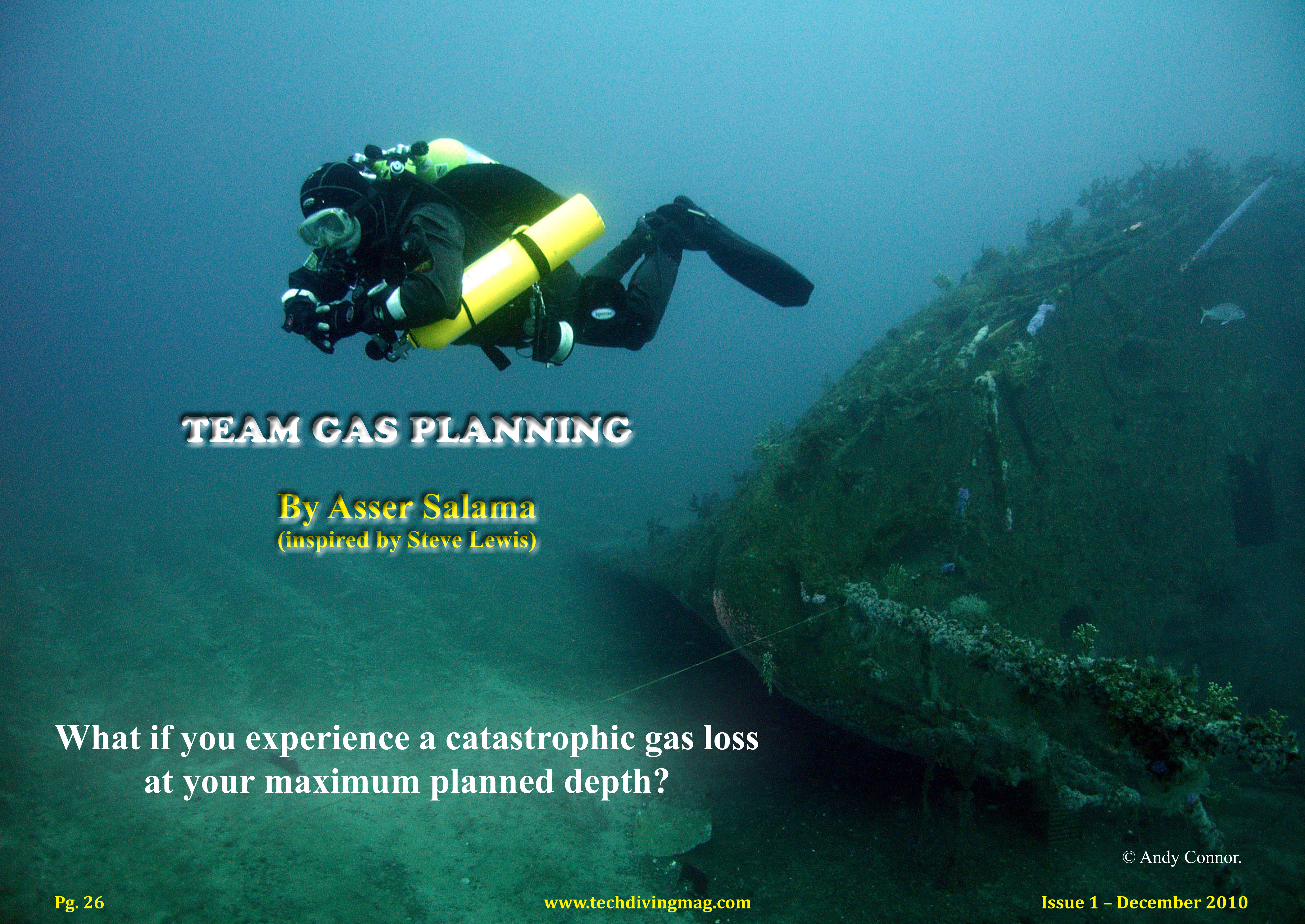
Tom and I volunteered, after all it was his idea in the first place and it was me that tracked down the location. Fairs fair, right? We geared up and set off across the mud flat towards the steps. We knew it wasn't going to be easy, and sinking up to your knees in sucking mud tells you two things – get in the water and swim, and don't expect perfect vis. I broke out of the mud and took the swim option, but Tom was having a harder time of it – his drysuit boots are too large, and every step he'd try to pull his foot out of the mud, but all that would happen is that his leg would move inside the drysuit leaving the actual boot in the mud…. Eventually, he too made it into the water and swam across to where I had fixed a line to a fence post. The plan was to reel out down the ramp and tie it off on any part of the remaining buildings that we could find. Looking into the water, it wasn't looking that clear – we'd definitely need the line to find our way back.

Sometimes, it is better to travel hopefully than arrive.

We started our descent, at 2m it was dark. The silt in the water obscured everything. My HID light was barely visible even though I was shining it into my eyes. Tom was nowhere to be seen. I stopped and waited, and then I didn't see him but felt him bump into me. This is not good. Sorting the line out, I carried on down but could feel the current pulling us sideways off the ramp. At this rate, we'd miss the buildings completely. I couldn't see the bottom, but reached down to touch it and a cloud of silt billowed up. Feeling the concrete ramp, I pulled myself down it a bit further and the vis seemed to be getting better – I could nearly see something, as opposed to nothing! I looked behind me, Tom was nowhere to be seen and the line was snagged around a plant and the current had dragged it out into a huge loop. Was going on a good idea? I looked at my computer, 9m and 2 minutes. Tom was still nowhere to be seen – I made the call, and turned around. As I reeled in the line, I bumped into Tom at about 5m. In the murk, I gave the up signal – I wasn't enjoying this, and even if we found something down there… what were going to do, feel for openings and hope that it would be safe to penetrate? Maybe we'd found the reason that no one we knew had ever dived Horahora Power Station.

Surfacing, we untied the line and opted for the long swim back to the entry point rather than trying the sucking mud flats. Even then, getting out of the water wasn't easy – taking my fins off, I stood up and immediately sank into waist deep mud. Never again would either of us curse Lake Pupuke, there is a lot of silt in this part of Lake Karapiro! Making it back on to firm ground, there was just the long walk back to the car. The council's contractors working on the access road must have been bemused, as Tom and I stomped past in drysuitwinsets on our backs! You could see their thoughts, "Crazy Fools!", but when it comes to true exploration diving you have to take the rough with the smooth. Who knows, maybe one day we'll be back? After all, it's only a couple of hours away and conditions can only be better!

Dr Andy Connor
Senior Lecturer & Associate Director of SERL
Auckland University of Technology
http://serl.aut.ac.nz



TEAM GAS PLANNING

By Asser Salama
(inspired by Steve Lewis)

What if you experience a catastrophic gas loss at your maximum planned depth?

© Andy Connor.

During our recreational dives, we usually surface with 30 to 50 bars (around 450 to 750 PSI) for "safety". At the end of the day, recreational diving is no-stop diving, meaning that in case anything goes wrong, one can just surface. On the contrary is technical diving; one can't just surface in emergency situations because of the decompression obligations. That's why we keep aside some reserve. We say it's for contingency, and we already have several ways to plan this contingency, the most popular of which is the Rule of Thirds.

The Rule of Thirds simply states that a diver should use only one third of his bottom mix to descend and spend some time at the maximum planned depth. Another third is for spending some more time at that target depth and ascending to the first decompression stop (or wherever the first gas switch is). The rest of the bottom mix (one third) is reserved for contingency. Depending on the dive conditions, depth, plan and number of divers, some tend to modify the Rule of Thirds so that even more gas is reserved for contingency. Normally this amount of extra reserved gas is in the range of 300 to 500 liters (around 10.6 to 17.6 cubic feet), yet some divers end up keeping aside half of their bottom mix.

But what type of contingency? One of the most important principles of technical diving is to always have enough gas to safely bring both you and your buddy to the surface; in any case – whatever happens. One big issue is to have a catastrophic bottom gas loss. Now both you and your buddy need to reach the first gas switch point safely. The diver who experienced this gas loss will have to share his buddy's gas, and there's no other way around. In other words, the extra gas you carry is for your buddy's safety, and vice versa.

Since gas consumption rates vary from diver to diver, it is not unusual to see divers carrying tanks of different capacities. If my consumption rate is not as good as my buddy's, I can simply carry bigger tanks. At least that's what we used to do in recreational diving.

Since the extra gas I'm carrying is primarily for my buddy, let's do a simple matching process to be sure that everything will be fine. My buddy will be carrying twin aluminum 12 liter tanks (AL85s). Since I'm not as good on air as him, I'll be carrying twin aluminum 15s (AL106s). All the tanks are filled up to 200 bars (2,900 ~ 3,000 PSI). Now that's a total of 4,800 liters (170 cubic feet) for my buddy and 6,000 liters (212 cubic feet) for myself.

Since it's only the two of us on this dive, it's preferable to use the modified Rule of Thirds. Each one will keep aside an extra reserve of 300 liters (10.6 cubic feet). So now my buddy is carrying 4,500 liters (almost 160 cubic feet) and I'm carrying 5,700 liters (almost 200 cubic feet). It happens that each one will consume his two thirds within the same time frame of the other, meaning that the bottom time matches perfectly with our different consumption rates and carried gas volumes. Now that's really nice!

But let’s consider that after consuming the first third and reaching the turning point on the bow of the wreck we’re diving, I suddenly lost the rest of my bottom mix. Now the rest of my buddy’s gas (4,500 * 2 / 3 + 300 = 3,300 liters ~ 116 cubic feet) should bring us back to the anchor line. My consumption during this leg will be 1,900 liters (67 cubic feet) and his will be 4,500 / 3 = 1,500 liters (53 cubic feet). So the total required gas is 1,900 + 1,500 = 3,400 liters (67 + 53 = 120 cubic feet), which is 100 liters (almost 4 cubic feet) more than what we have in hand!

Where does this problem stem from? **Well, again, the extra third you’re carrying is for your buddy, not for you. My buddy should have kept one third of my gas with him. In other words, he should have calculated the needed reserve as 5,700 / 3 liters (200 / 3 cubic feet) not 4,500 / 3 liters (160 / 3 cubic feet), in addition to the extra 300 liters (10.6 cubic feet) then plan the dive accordingly.** Of course it’s a buddy team fault. Gas matching is the responsibility of all the divers involved in the dive.

Don’t you think it’s easier to carry similar capacity tanks?

Asser Salama
Technical Diving Instructor
asser@red-sea-shadow.com

HISTORY OF DEEP DIVING
(through 1995)

By Bret Gilliam

"Naturally, like any explorer,
I have been asked what I intended to find,
and whether it made any sense to take unavoidable risks…
I did not expect to find pirate's gold in brass bound boxes.
It's more the feeling of adventure,
the great feeling of putting your foot
where no other has been before."

Dr. George Benjamin

"Once a man has been bitten by the diving bug, he's done for. For there's nothing that can be done against this mania, either by fair means or foul. No nook or cranny seems safe from manfish, no cleft, no cave too deep or too dark. He seems to have a close affinity with the members of the mountaineering fraternity. The latter also risk their lives for an experience of a special kind… For them too, it is not really the rock face or the mountain that has to be overcome, but their own selves."

Hans Hass

THE RECORD HOLDERS

It's April 5th, 1988 in Tamaulipas, Mexico and even though it's a bright, hot, sunny day Sheck Exley is cold and alone in the dark. Oh yeah, he's also nearly 760 feet deep in Nacimiento del Rio Mante cave system in pursuit of the deepest dive ever accomplished by an independent, untethered, surface to surface diver. Right now he's got a little problem: over 100 feet deeper than a free-swimming diver has ever been and almost 450 feet deeper than his nearest alternate gas source (cylinders staged at 320 fsw), he has paused to check his pressure gauge that monitors the TRIMIX (He / N_2 / O_2) tanks on his back.

Even on mixed gas, there are traces of narcosis at this depth. The small percentage of nitrogen in his mixture has produced a partial pressure this deep equivalent to approximately 260 fsw on compressed air. He has been fighting an upflowing current for over twenty minutes on his descent and time has become a factor. "As I entered the unexplored cave zone, I was concerned about the slower than expected rate of descent. I forced myself not to pick up the pace. Instead of continuing its vertical drop, the crevice began to narrow and run at a 60-degree angle. Flashes of narcosis were becoming more prominent. I glanced at my pressure gauge; the reading hadn't changed since my last check. I banged the unit on the tank. The needle jumped a few hundred pounds lower. Pressure had forced the lens against the needle, but had it stuck again? I had no way of knowing. A projection to tie off on was just below. I passed it and dropped deeper. The tunnel began to flatten out, falling at a 45-degree angle. I looked at the pressure gauge; it showed a third of the gas was gone. Was the reading correct? I had been down just over 22 minutes. It was time to get out."

"My light beam fell on an excellent tie-off 20 or 30 feet down. I took a breath and moved toward the projection, when suddenly a jolting concussion nearly knocked me unconscious. I tried to look behind me for a ruptured valve or hose. There was no leak. Something had imploded from the pressure, but what? I drew another breath and kicked the last eight feet to the tie-off. Quickly I threw two half hitches around the rock, reeled in the loose line and made the cut. My down time was 24 minutes, 10 seconds."

Suspended at 780 feet, Exley has shattered the old mixed gas depth record (set by Germany's Jochen Hasenmayer) by 124 feet. But the surface was still a long way up and the implosion shock was numbing.

"I wanted to move fast from the deep water, 120 feet a minute if possible. The current that I had battled during my descent helped to lift me up the incline. I drew a breath and felt a slight hesitation from the regulator. The next breath came harder. Was I out of air? Again, I hit the gauge on my tank but this time the reading didn't change. If I was forced to use the gas in my belly tank, I would miss all the decompression to 330 feet where my first stage bottle was tied off. I switched over to my back-up regulator and with relief drew a full breath."

Proceeding steadily upward in the chasm, he reaches 520 feet and retrieves his conventional depth gauges where he has tied them off. Beyond this depth he has had to calculate depth by means of a knotted line since no gauges had yet been made to handle such pressure.

"At 520 feet, it was strange to be decompressing at such a depth. I knew that only one person had ever gone deeper. I remained a minute and then began to ascend at the rate of ten feet a minute until I reached 340 feet. When I saw my first stage bottle and knew that I had spare gas around me, I finally began to relax. My stress was gone, but the long decompression stops were only beginning."

For 22 minutes bottom time, he would pay a decompression obligation of nearly ten and half hours followed by thirty minutes breathing pure oxygen at the surface.

"Now with the extra time, I began to search for the cause of the deafening implosion. The source was the large Plexiglas battery housing for my primary light. The pressure had been so great that the three-quarter inch lid was forced into the casing crushing the battery pack. Amazingly, the light still functioned."

Sheck completed his decompression uneventfully and surfaced at 9:30 PM wrinkled and exhausted. Hours later, support diver Ned DeLoach broached the inevitable question:

"Will you ever do it again?"

Exley paused and considered his answer, "I don't know."

Only days before his 40th birthday and almost exactly a year later on March 28, l989, Sheck Exley eclipses his own world record in the same cave reaching 881 feet!

There is good reason that he is considered to be one of the finest scuba divers of all time. But what makes his accomplishments all the more compelling is that he has devoted virtually his entire career to the most challenging diving environment of all: deep caves. A veteran of over 3000 cave dives, Exley is the undisputed king of the hill. But he remains an almost reluctant hero, virtually unknown until recently outside of the cave and "high tech" communities. In addition to the mixed gas record of 881 feet, he holds the record for longest swimming penetration into a cave: a 10,444 foot push into Chip's Hole, a sinkhole in Tallahassee, Florida. He also set the record for longest scooter/DPV penetration at Cathedral Canyon at 10,939 feet, a distance of over two miles!

Sheck is also a prolific writer with over 100 articles and six books to his credit. He has been honored as a Fellow of the National Speleological Society and was a recipient of the prestigious Lew Bicking Award as America's top cave explorer. Even so, "experts" gave him only 50/50 odds at best to survive the 780-foot dive. His custom TRIMIX tables were totally experimental having been developed by decompression physiology pioneer R.W. "Bill" Hamilton. The computerized tables called for Exley to stage sixteen bottles and then carry four tanks with him for the final drop. Eleven different blends of TRIMIX were used with 52 decompression stops. The following year on the 881 attempt, the skeptics were less vocal. That required 34 stage bottles and thirteen and half hours of decompression. It's strictly limited participation at this level of diving, Sheck essentially can compete only with himself.

Although the mixed gas record changed hands almost annually for a while until Exley made it a one-man-show, the depth record on compressed air set by Neil Watson and John Gruener in 1968 seemed destined to hold up forever.

Both men trained intensely for a year prior to their record dive to 437 feet in the Bahamas. With the benefit of an almost 25 year perspective, their accomplishment is nothing short of phenomenal. Lacking the equipment advantages of high performance regulators and modern buoyancy compensators with power inflators, Watson and Gruener operated against incredible performance deficits. And the attempts of other record seekers offered a hodge-podge of success and tragedy.

Frederic Dumas, a colleague of Jacques Cousteau, established one of the earliest credible compressed air diving records in 1947 by reaching 307 feet but reported severe narcosis. Four years later, Miami lawyer Hope Root set out to attain 400 feet in the clear blue water of the Gulf Stream. At 52 years of age and with little practical experience in working up to such a great depth, his attempt seems particularly ill advised.

Hans Hass speaks of Root's quest, "Many menfish, like men on land, have, so to speak, a screw loose. They are dare deviltry personified. But even so, they cannot be described as brave, since courage is the conscious mastery of a fear, quite naturally correlated with danger. Into this category must be placed Hope Root."

The dive plan was for him to enter the water wearing doubles and descend beneath a boat drifting in the current. No descent line was used, so the boat would track his progress and record his depth with an echo sounder (similar to sonar). A band of local press and representatives from *Life* magazine were present to witness the record. Several underwater photographers joined Root in the water including veteran Jerry Greenberg. Around 70 feet, Root paused in the water column and looked back up to the surface perhaps considering his fate. He then began swimming down into the bottomless Gulf Stream canyon. Greenberg followed him below 100 feet and continued snapping photos including a haunting portrait of Root drifting away in clouds of bubbles from his double hose regulator. As he passed the 300-foot level, Greenberg lost sight of him forever.

Meanwhile on the boat, the depth finder etched Root's progress and wild applause broke out as he passed the old record at 330 feet. Continuing his dive to destiny, he paused for almost two minutes at 430 feet (recorded on the echo sounder as a horizontal line at that depth). Then to the amazement of the onlookers, Root dropped another ten fathoms to 490 feet. Hesitating only briefly now, he dived to 500 and on to 650 feet before the echo sounder went out of range. Silence settled on the boat as the horrified witnesses realized that Hope Root would not be coming back. His body was never found.

In 1959, Ennio Falco of Italy reportedly reached an approximate depth of 435 feet but had no means to record it. In a subsequent dive to a lesser depth he drowned during decompression.

In the early 1960's, Jean Clarke Samazen declared, "All sports must have a champion. I want to be the champion of scuba diving." Wearing the ultimate in a cylinder package for his day, he utilized doubles on his back and his chest to reach 350 fsw. The rig was awkward, at best, but provided incredible air volume! An early *Skin Diver* magazine account described him as "looking like a large sandwich." Hal Watts, who is still teaching advanced deep diving today, beat Samazen's record to 355 fsw.

Tom Mount and Frank Martz, two of the United States' cave diving pioneers, experimented with several 325 feet plus dives in the early sixties eventually setting a new compressed air mark for depth at 360 fsw in 1965. Hal Watts and A. J Muns posted a new official record in 1967 attaining 390 feet. One year later Watson and Gruener were poised on their historical threshold. They knew that narcosis and oxygen toxicity had claimed many of their forerunners. Both men were students of Watts and by 1968, they had discovered the value of "adaptive" dives to reduce these effects. They would descend together down a weighted cable and attach clips to it to certify the depth. Although they reached 437 feet, a new world record, both were so affected by narcosis that they could not recall even clipping on to the cable. When asked what it was like on air at 437 feet, Neil Watson replied, "I don't remember".

One of the last serious assaults to the Watson/Gruener record was planned in 1971 by the well-experienced team of Archie Forfar, Anne Gunderson and Jim Lockwood. Sheck Exley, then 22 years old, was brought in as a support diver. Lockwood set up a regimen of progressively deeper dives for training purposes near the Andros drop-off walls. Although, the youngest member of the dive team at 21 (Forfar was 38 and Gunderson was 23), Lockwood had the most deep diving experience with numerous dives to 400 fsw and deeper. (In 1991, barring the sudden emergence of a credible challenger, he still remains the record holder for most dives below 400 fsw with almost 150 totaled in his career.)

Lockwood was visiting Tom Mount in pursuit of exploring the virgin "Blue Holes" in that area of the Bahamas when he was introduced to Archie and Ann. They had been making dives in the 380-400 fsw ranges and a discussion was initiated into the possibility of breaking the Watson/Gruener record. It was decided that they would work together and attempt 480 fsw. During the work-up dives, they made 40 dives below 400 fsw including 25 approaching 450 fsw (as measured by SCUBAPRO's helium depth gauge). They experienced no significant difficulties of impairment during the practice dives and on December 11, l971 considered themselves ready for the official record attempt.

Forfar had decided to use a weighted cable similar to Watson and Gruener for descent and a "traveler" clip system that would slide down with the divers to record their maximum depth. In 1990, Exley provided this retrospective:

"For this attempt, Archie had designed an ingenious but simple system of drop-way weights to insure their survival. When losing consciousness from narcosis most divers will retain their regulator and continue breathing. All the dive team members had to do was to make sure that their BC's were fully inflated during the descent and hook some weights behind their knees. These would automatically drop away when the legs were straightened if a black-out happened and the diver would float up where I could recover him."

However, on the day of the record attempt things went awry. It was discovered that the clips for the cable would not slide freely. Lockwood discussed the events of that day nearly 20 years later:

"We had an engine block attached as the deadweight on the end of the 480 ft. cable but we had never unspooled the cable prior to the dive. When we did at the dive site we found it had a tendency to bend and sort of 'hockle' and wouldn't hang straight and true. The dive plan had to be changed." Forfar and Gunderson elected to abandon the fall-away weight system and make the drop with empty BC's. Lockwood stayed with the original system and would descend with his BC inflated."

Lockwood relates, "I still wanted to use the positive buoyancy safety factor in conjunction with the weighted bar but Archie and Ann had their own ideas and decided not to. Almost immediately into the descent I realized that I was in trouble. The cable was oily and greasy and I got the stuff on my hands. This made it almost impossible for me to get any grip on the inflator valve for the pony bottle that fed air into my BC. I was dropping like crazy because of the weight behind my legs and I could not get anything into my vest to counteract this excessive negative buoyancy. My descent rate was probably in excess of 200 feet per minute. I remember thinking that Archie and Ann were not keeping up with me and I was frantically trying to wipe off my oily hands on my wet suit. This was requiring considerable energy and a lot of stress and eventually at some point I passed out."

Exley, in his role as safety diver hovering at 300 feet, became witness to the ultimate deep diving nightmare. Somewhere in the depths, Forfar and Gunderson lost control. Lockwood lost consciousness below 400 feet and floated up to Exley who verified that he was okay and then made a heroic attempt to locate the two deeper divers. He descended well below 400 feet in his desperate attempt to save his friends but was unable to rescue them. They were not recovered.

The safety divers had agreed not to go beyond 300 fsw but when it became apparent that Archie and Ann could not come back on their own, each made a personal decision to attempt the rescue. Bill Wiggins and Randy Hylton made a simultaneous effort but were severely impaired by narcosis at 360 fsw and nearly 400 fsw respectively. Exley was left alone and remembers:

"The horror was even worse. From 400 feet on down, I could see Archie and Ann still breathing on the steeply sloping wall. Archie had his head down against the engine block and was still slowly kicking as if he were going down the cable, and Ann was lying on her back about 10 feet off to one side. I started to get severe tunnel vision and it was all I could do just to be able to survive at that depth. The last distance to Archie might as well have been a mile."

Lockwood speculates, "I know I never got that inflator valve open and I think it's possible that I ran into the engine block when I bottomed out the cable. Archie probably was OK at that point but expended so much energy trying to inflate my BC that he succumbed to narcosis himself. Ann would never have left Archie so that would account for their double accident. I was out of it so I don't know what happened, but I have no recollection of anything after about the 400 ft. level and I doubt if I ever got any air in my vest. Archie probably saved my life. I don't even remember floating up to Sheck although he says I gave him the OK sign at that point. I really didn't come around until about the 50 ft. decompression stop."

Two decades later, professional diver Bret Gilliam is preparing to break Watson and Gruener's record that remains intact. All challengers to that record have died trying except Lockwood. Gilliam is unperturbed. He has devoted almost a year of adaptive diving and extensive research in physiological effects of depth on humans and other mammals. His work has included over 600 dives in the previous 11 months with 103 dives below 300 feet. He also has made use of recompression chamber dives to experiment with varying high partial pressures of oxygen to simulate conditions below 400 feet.

Like Exley, Gilliam has been professionally involved with deep diving projects for over twenty years. Since 1959, he has logged in excess of 12,000 dives around the world. Over 2000 of those have been below 300 feet. For 15 years he owned one of the Caribbean's most successful dive operations before selling out in 1985 to spend three years cruising and diving on his 68-foot motor yacht while doing diving and marine engineering consulting projects through his company Ocean Tech. Now (in 1989-90) he is under contract to Ocean Quest International as a corporate executive, Captain and Director of Diving Operations for their 550-foot dive/cruise ship. It's the largest sport diving program in the world.

From the outset, he set that ship up to support his "technical" diving interests and launched a carefully conceived one year project to see if the compressed air record could be targeted with an acceptable assumption of risk.

"In the beginning, I wasn't even concerned with a record dive. I did not even remember what the record was. Later as I got nearer to it, I went back and looked it up and found that I was getting very close and that kind of jogged my interest. But I was really just getting sick and tired of listening to supposed experts make sweeping statements about deep diving that were so totally inaccurate that I finally just decided to see what I could do; more to disprove the misinformation that was postulated than to prove anything. Hell, at this point, NOAA had Gary Gentile tied up in Federal Court fighting an injunction prohibiting his access and right to dive the Monitor *wreck. They had omnipotently informed him that 230 feet was too deep to be dived safely. Here they are telling one of America's best deep divers that he can't make what for him was a routine dive. What a crock!"*

At the time, Gilliam was sponsoring an Ocean Tech study of dive computers and testing several of the models to their limits with frequent 300 foot plus dives weekly. The ship's onboard recompression chamber facility provided an ideal lab for several experimental dives. By January 1990, he decided that his adaptive level and physical training was sufficient for a major attempt at depth. A chance meeting with custom table producer Randy Bohrer provided the basis for air tables to 500 feet.

"The tables process was involved and required extensive field work. Randy would cut a table with his recommendations and send it off to me on the ship. It might take three weeks for me to get it and try it out. He leaned to a more conservative model and I kept modifying it based upon some work I had done with the Navy on exceptional exposure proprietary tables under development back in the early seventies in the Virgin Islands for an ASW (anti-submarine warfare) project. Most of our work was conducted observing hydrophones and submarines in the deep canyons between St. Croix and St. Thomas. This required pushing the 400 ft. plus barrier on several occasions. We had a lot of problems with sharks during decompression in the open ocean and experimented with all kinds of theoretical models to shorten our hang times."

After five months of fiddling with Bohrer's successive offerings, Gilliam had dramatically altered the decompression schedules to minimal times with a margin for safety:

"But we were completely breaking new ground; no one had ever field-validated air tables to these depths. I felt confident that we were on the right track and I was having no problems with the extreme profiles I

was running. But it was nice to know that I had the chamber right on-site. Without that security, I doubt if I would ever have done diving this deep so aggressively."

In addition to various instructor affiliations, Gilliam is a licensed USCG Merchant Marine Master and recompression chamber supervisor. He directs all treatment protocols and therapy for ship divers and occasional locals who get DCS hits. He has no intention of requiring his own services.

"This type of diving is a mental exercise. You have to understand the physiology and mechanisms of narcosis and oxygen toxicity to survive. Many academicians dismiss deep diving as suicidal with very little real-dive experience to justify their arguments. I have an overwhelming respect for the risks involved and seek to provide every edge I can get through education and planning. Prolonged facial immersion breathing to invoke the diving reflex and other little tricks are all vital pieces of the equation to minimize CO_2 in the narcosis and O_2 tox responses."

He will make his descent at 100 feet per minute only slightly over-weighted. Ten minutes are spent on the surface prior to the dive with his face in the water breathing through a snorkel and then five minutes more with no mask breathing from a spare tank at 15 feet below the boat. This invokes the physiological "diving reflex" response. Surfacing only long enough to dry off his face, he begins the descent. His heart rate and respiration will drop significantly on the dive. 12 to 15 beats a minute with deep slow ventilations of one to two per minute are typical for him.

The dive site selected is known as Mary's Place in Roatan. He has picked this spot due because of its near vertical wall configuration offering immediate access to abyssal drop-off depths. The day is Wednesday, February 14, 1990; eleven days after Gilliam's 39th birthday. Visibility is 100 feet at the surface depths and over 200 feet in the deep zone, water temperature is 81 degrees and no current. Conditions are ideal.

Only a handful of staff are aware of the upcoming dive. Just before he enters the water, one safety diver asks if he can borrow Gilliam's gold Rolex watch until he comes back. Another asks for his TV and stereo; a third wants his spacious senior officer's stateroom on the ship. The local Roatan deckhand wants his girlfriend. Gilliam keeps the watch.

His gear is kept to a minimum. A single cylinder pressurized to approximately 120 cubic feet with a high performance regulator attached with DIN fittings. A back-up second stage and two pressure gauge consoles with helium depth gauges calibrated to 500 feet are plumbed into the regulator first stage. Three dive computers with a Casio watch are attached to one console. He discovered by accident that the Beuchat computer (made by UWATEC, a company he would later take over in 1995) will accurately read depth digitally to at least 500 feet. He finds digital gauges far easier to read under the influence of narcosis. The computers will not provide any valid decompression information but their depth gauges and timing instruments will hopefully survive the pressure.

Slipping over the wall, he reaches 300 feet in just under three minutes. His descent picks up slightly now and one computer "locks up" in error mode at 320 feet. A large remora fish that has followed him since the 150-foot level is becoming distracting:

"Here I am at 300 plus feet dropping like a stone with every nerve and impulse in my body going through a self-check a million times a minute for any warning sign of severe narcosis impairment or O_2 tox,

and now I've got some damn friendly fish wanting to play with me! It kept swimming in and out of vision and my eyes didn't want to focus on my instruments and the fish simultaneously. I almost had to abort but it finally moved down towards my thigh and out of my vision path so I decided to ignore it. "

Approaching 425 feet he begins to inflate his BC while timing his inhalations so the regulator would only have one volume demand on it at a time. He drops an eight-pound weight belt and it disappears. Because his computers are calibrated in feet of fresh water he has prepared a 3% conversion table so he knows exactly where to stop; in large bold instructions on a slate is written: "464 FT: STOP!" He hangs motionless perfectly suspended about five feet from the wall; four minutes and 41 seconds have elapsed since leaving the surface.

There is plenty of ambient light even this deep. He retrieves a slate with ten problems involving math, simple word problems, daily event questions etc. (i.e.: what day is it? what time is it? 3 x 10 x 22 = ? ...) It takes one minute and 40 seconds to work the problems; he has not seen them before and it takes longer to finish than he expected. He slips slightly deeper by two feet and the computer will record 466 feet as the maximum depth. Later, all agree that 452 feet of seawater is a reasonable conversion; a new world record on compressed air by 25 feet.

Six minutes and 20 seconds have ticked off, time's up. Ascent commences at just over 100 feet per minute and he slows to 60 ft./min. at a depth of 100 fsw. The first decompression stop is at 50 feet. One hour and sixteen minutes later he surfaces and breathes pure oxygen at the surface for twenty minutes via demand mask. Although some handwriting flaws are apparent, all the test questions are answered correctly. "I've got lousy handwriting anyway," he replies defensively with a laugh.

"Narcosis is there but not to a level that I was uncomfortable with. Impairment is specific to individuals. O_2 tox is the real unknown; that scares me but I had no problems at all. I planned this dive to preclude virtually all exertions. Perhaps I'm an exception to nature but I suspect my conditioning through long-term experience and adaptation due to diving constantly in deep situations plays a far greater role. Calculated risk is the operative phrase here. What is attainable for me is possible because of my commitment to detail and training and total discipline during the actual dive process. I also had a positive mental attitude; I knew I could do it."

Gilliam's plans called for an attempt to 500 feet later but he postponed that after leaving the Ocean Quest contract to pursue other business interests.

"I think that 500 feet would have been possible for me if I had followed closely on the heels of the 452 foot dive. But when I came off the ship, I was away from deep diving for a while and felt that I had lost the adaptive edge I had acquired. And I wanted a chamber overhead. In the right circumstances, I might try it if I had the time to work up to it again. If you could do the drop in five minutes I think you could handle the O_2 exposure. Who knows? No one believed that 450 feet was possible."

Exley and Gilliam conducted record setting dives that were vastly different in many ways but with one common denominator: Both elected to dive alone, regarding the presence of another diver as a potential liability. And both showed a single-minded intensity of preparation that was unprecedented.

Some critics will pontificate that such dives are reckless, crazy, without purpose... but man's competitive motivation is best exemplified in such individuals. Life is full of challenges: Chuck Yeager breaking the sound barrier to "push the outside of the envelope", Sir Edmund Hillary climbing Mt. Everest "because it's there", and now Sheck Exley and Bret Gilliam diving deliberately to bottomless depths "because it's not there!"

The point of any human performance record is individual and reduced to its simplest form: Doing what others cannot do. And that has to be a personal decision. Dangerous? Yes, extremely so. But the personal risk to these individuals was acceptable to them and their success a triumph. Neither Exley nor Gilliam advocate such extreme diving for others. Will those records ever be beaten? Both men think so.

UPDATES SINCE 1991

In fact, Gilliam and Exley would both make attempts on their own records in 1993 and 1994. Gilliam reached a depth of 490 fsw in October of 1993 to best his existing record on compressed air. He had no reported narcosis or oxygen toxicity problems on the nine-minute dive.

At least one diver attempting to better the compressed air record was killed in 1992 when he disappeared off the north shore drop-off wall on the island of St. Croix in the Virgin Islands. This individual swam from the beach (without surface support or safety divers) to the dive site, a distance of nearly a quarter mile. He had discussed his dive plans to reach 500 feet with friends and had made some earlier dives close to 400 feet in the preceding months. On the day he had picked for his record attempt, he departed alone and was never seen again. His locked car was found parked by the beach entry.
Later that same year, a dive store instructor from Hollywood, Florida apparently reached a depth of 455 feet while diving in the Gulf Stream but was reportedly caught in a down draft current after attempting to abort the dive. He was only aware of his actual depth when he managed to fight his way up to shallower water. Several onlookers considered his attempt ill-planned and badly executed. Others regarded his survival as a miracle. No official reports or dive profiles were ever offered and it has been reported that this individual ceased deep diving shortly thereafter. Nonetheless, his record was recognized at least as a *survival* record from an aborted dive until Gilliam went to 490 a year later.

The current compressed air record was set by Dr. Dan Manion on March 18, 1994 when he reached a depth of 509 fsw. Manion had successfully made several other deep dives that broke the 490-foot mark. Indeed, the day before his record he had reached 491fsw at the same site, Clifton's Wall off Nassau in the Bahamas. Confident after that success, he planned to reach 500 fsw the following day. He had undertaken extensive correspondence with both Gilliam and Tom Mount in the previous year leading up to his record. He had also adhered to a rigorous personal training regime that dropped nearly 40 pounds from his frame and dramatically increased his overall fitness.

"Everything started out fine that day: sunny skies and a light breeze across the calm ocean with a comfortable temperature in the mid-seventies. Manion recounts, "Gearing up went smoothly and after a short surface swim, my safety diver and I relaxed on the surface. We went through our check lists for gear and decompression and then descended." Two minutes and ten seconds into the dive Manion passed 330 fsw as his partner waited at 200 fsw. "Visibility was about a hundred feet, I felt in control. I remember having to fin away from the wall due to the mildly increasing slope. At 450 fsw, I added air to my BCD in short bursts. As the numbers slowed on the computer, I picked a touch down spot some 20 feet below me."

That's apparently when the trouble started. Because he remembers absolutely nothing from that point in the dive until he found himself ascending in a cloud of foam and bubbles.

"The beep of the fast ascent alarm was actually reassuring to me as I came around. I had no memory of turning the dive or what depth I reached. My light and lift bag were gone along with my descent weights. I could see my safety diver at 150 feet easily and I began dumping air from the BCD. We exchanged OK signs as we linked up. It was not until I checked my computers that I realized how deep I'd been. Later as I exited the water, I felt sad that I had worked so hard to get to this point and then couldn't remember it. I'm positive I have reached my own physiological limits. I have no further plans to push this envelope."

His two Monitor II dive computers recorded conflicting maximum depths (registered in feet of fresh water). One indicated 506 but the other notched 525. Corrected for seawater that would be 490 and 509 fsw respectively. Manion has no idea what depth he attained but suspects that 509 is correct since his other unit may still have been displaying the dive from the day before.

Exley and others discount a record in which the diver blacks out since they were not in control. But Gilliam points out, "Dan made it to 490 the day before in complete control and with no problems at all. That's deeper than anyone has made it to before except me. Maybe 500 feet is a psychological wall as well as a physical one. One thing's for sure, I'm probably getting too old to ever find out now."

Although Gilliam would break his own record at the age of 42, Exley's own attempt to reach 1000 fsw on mixed gas in April 1994 at the age of 45 would end in tragedy.

ZACATON

Zacaton is the deepest of five cenotes located on a large ranch, El Rancho Asufrosa, in northeastern Mexico. It was "discovered" on a reconnaissance trip made at the end of two weeks of exploration and surveying in the Nacimiento Santa Clara, a cave system at the base of the El Abra near the Nacimiento Mante. The exploratory team led by Jim Bowden and Ann Kristovich had laid more than 1400 ft. of line in the Santa Clara, but had ceased their efforts due to the depths encountered in the distant reaches of the cave. More than 1100 ft. back, depths exceeded 250 ft. At that time, 1989, the team was not routinely employing mixed gas techniques in their exploratory efforts in Mexico. The door to the Santa Clara was temporarily "closed". Jim had studied geological survey and topographical maps which revealed the possibility of inland "cenotes" in the karst terrain found at the southern extreme of the Sierra de Tamaulipas.

On a ranch near the small town of Aldama, five cenotes of variable size and character were located. Exclusive entry and permission to dive was granted by the owner and in late April 1990, exploration began. The cenotes proved to be extremely unusual. They are aligned generally east to west within a radius of approximately two miles. They are highly sulfurous in odor, in one named Poza Asufrosa, the sulfur precipitates and floats on the surface in raft-like formations. The waters discolor, and tarnish all metals, and seem to leech the surface of galvanized tanks. The systems are surprisingly warm, 93 degrees in Poza La Pilita, 87 degrees in Zacaton, 86 degrees in Poza Caracol, 87 in Poza Asufrosa, and a cooler 83 degrees in the huge oasis-like Poza Verde. Unlike the others, the waters in Poza Verde are layered in thermoclines and behave more as a lake in times of flood and drought and seem less responsive to the changes imposed by the water table.

The team began the systematic exploration of the cenotes. Initial efforts

The team began the systematic exploration of the cenotes. Initial efforts were concentrated in Poza La Pilita. This 68 ft. by 120 ft. ceynote is the warmest of the five at 93 degrees F. The surrounding walls reveal tufa formations often associated with warm thermal springs. The sidewalls are coated with a dense algae that hangs like curious stalactites. Measurements made using the SCUBAPRO personal sonar device revealed a system that enlarges significantly with increasing depths. At 150 ft., La Pilita is 396 ft. from north to south and 239 ft. from east to west. The team initiated the search for a connection to the cenotes located immediately to the east or west; however, no ongoing passage was found in the early exploration. The depth of La Pilita was plumbed to 360 ft. and dives were made to 250 ft. On May 2, 1990, divers Jim Bowden and Gary Walten entered the Nacimiento at the western boundary of the ranch. The river is formed by the spring run emanating from Zacaton. A typical "boil" was noted on the water's surface near a limestone outcropping.

Pursuing this current, the divers located a small cave and followed a northeast azimuth until they had exhausted the line on their reel. With passage obviously continuing, they turned the dive, obtained an additional exploratory reel, returned to their tie-off and resumed laying line. Now in the lead, Gary soon noticed a bottle green glow ahead. He covered his light and confirmed a natural light source that could mean but one thing, they had made a connection to the surface. The exuberant divers emerged into Zacaton at a depth of 26-ft. and surfaced in the beautiful cenote which takes its name from the islands of tall grass, *zacate*, which float across it's surface.

The succeeding days were spent surveying the nearly 600 feet of passage (named El Pasaje de Tortuga Muerte for the frequently encountered turtle skeletons) connecting the Nacimiento and Zacaton and recording baseline information on this impressive system. The surface of Zacaton is approximately 70 ft. below the surrounding land. It is 380 ft. in diameter and roughly circular. It's lateral walls undulate and the system dimensions increase with increasing depth. A rough survey has been completed to 175 ft. of depth from the center of the ceynote using the SCUBAPRO personal sonar device. It is hoped that side scanning sonar techniques can be applied in the future to study the full extent of this cenote that is now known to exceed 1080 ft. of depth. The depth recorded for Zacaton in 1990 was erroneously measured at 250 ft. when divers Walten and Ann Kristovich dropped the weighted plumb line onto a prominent ledge that projects markedly into the cenote at 230-250 ft. Exploration continued on the ranch in August 1990 with dives by Karen Hohle and Ann Kristovich in Poza Verde.

This tropical oasis is greater than 600 ft. across, somewhat cooler than the other cenotes and surprisingly shallow, a mere 140 ft. by measurements in four quadrants. Bowden and Walten sought passage in Poza Asufrosa with side mount configurations, but the tight passage choked off after 30 feet of penetration. Caracol, like her immediate neighbor, Zacaton, sits beneath a cliff face. To date, only one dive has been made in this cave by Bowden, but he observed large going passage on an azimuth that would lead to Zacaton. The maximum depth in this system is not known as the passage travels beneath the cliff and could not be adequately measured by plumbed line. The maximum depth on Bowden's dive was 72 ft.

After this early exciting start, members of the Proyecto de Buceo Espeleologico Mexico y America Central spent the next two and a half years exploring cave systems associated with the inland Blue Hole of Belize. Solo efforts by Bowden from 1987 to 1988 had resulted in the connection of St. Hermann's Cave with Petroglyph Cave and the inland Blue Hole. The 1990-1991 efforts of the team added more than 1500 ft. of water filled passage to the survey, and discovered a previously unknown and spectacular pit in the jungle. Dives made in the downstream Boiling Hole follow an azimuth which will likely result in a connection to the Actun Tah system. Work was halted in Belize in 1992.

The "Proyecto" resumed the exploration of the five ranch cenotes in April 1993, fully equipped with mixed gas capabilities to allow the safer exploration of the deeper systems. Sheck Exley joined the team for a week and with Bowden dove the previously unexplored depths. La Pilita revealed at greater than 358 ft. of depth, going passage to the southwest. Zacaton however revealed the greatest surprise. On air dives to 258 ft. by Bowden and 407 ft. by Exley, no bottom was in sight. The previously plumbed depth of 250 ft. was proven to be an error! The divers dove beyond the ledge that had captured the measured line in pursuit of the elusive bottom. The following day, Bowden, Exley, and Kristovich returned to Zacaton to attempt a more accurate plumb. The line spun off the reel, past 500' past 800', past 1000'! The weight finally stopped after some 1080' had been measured.

The line was secured to the north wall of the cenote and the divers completed plans to make a deep mixed gas dive the following day. In April 1993, Bowden dove to 504 ffw. and Exley to 721 ffw. Tables for both dives were prepared using "Dr. X." software. Neither diver experienced performance difficulties or physiological complications during or after the dives. These two would be the first of seven sub-500 ft. dives made in Zacaton in a twelve-month period. As the week of diving came to an end, Exley and Bowden agreed to return together to Zacaton, and like Hillary and Norgay, pursue the exploration of the depths of this upside down Everest. The apparent perfect site for an open circuit dive to 1000 feet and beyond had at last been found. It was warm, there was no perceptible current, the natives were friendly, and access to the system was uncomplicated.

The goal was thus declared, that within the calendar year, a dive to obtain the bottom of Zacaton would be made by Bowden and Exley. Members of the Proyecto made six trips to Mexico during the ensuing twelve months. With each return, Bowden dove progressively deeper in order to prepare himself for the 1000-foot attempt. Exley meanwhile pursued the exploration of a huge underwater cave at Bushmansgat, South Africa, diving to 863 feet in this system. During this dive, Sheck experienced visual, somatic, and neurological symptoms of high-pressure nervous syndrome (HPNS). The symptoms resolved during his ascent to his first deco stop at 400 ffw. and there were no persistent effects.

In September, Bowden dove to 744 feet. Team member Kristovich dove to 554 feet, setting a new women's depth record with this effort. On December 2, 1993, Bowden made a dive in excess of 800 feet. The exact depth of the dive could not be documented as all three of the digital depth gauges he was wearing ceased to function at various depths ranging from 684 feet to 756 feet. Bowden, however, had visually noted the 825-foot marker on the descent line before reversing the direction of his dive. Bowden experienced multiple joint DCS upon the completion of his decompression obligation. Symptoms resolved following aggressive hydration, oxygen therapy and in water recompression. There were no persistent symptoms.

The 1000-foot attempt had been slated for December 25th; however, it was the consensus of the team in early December that the conditions imposed by the unusually wet rainy season were unfavorable for such an effort. The current in El Pasaje de Tortuga Muerte was fierce, and imposed a very undesirable heavy exertion dive prior to any deep attempt. It was necessary to traverse this nearly 600 ft. of linear cave passage prior to any dive in Zacaton, making all of the deep dives, in fact, repetitive dives. For the safety of the divers, the dive was rescheduled for April 1994.

In April 1994, the Proyecto, including Exley and Mary Ellen Eckhoff assembled on the Rancho Asufrosa. Two days were spent staging the required decompression bottles at their specified depths in Zacaton and El Nacimiento. The dive would be accomplished on independent descent lines, a condition both divers favored to avoid contact and potential interference during the very rapid descent. Each effort would be solo by necessity. Exley would use Heliair 6 as his bottom mix, Bowden, Heliair 6.4. Their tables were similar and were formulated utilizing "Dr. X." software. Both divers carried an assortment of tables since the exact time of descent (bottom time) and maximum depth of the dive was unknown.

Both Bowden and Exley made multiple deep air acclimation dives to prepare themselves for the 1000-foot attempt. Early in the morning on Wednesday, April 6, 1994, all was felt to be in readiness and the divers and their support team assembled on the banks of El Nacimiento. Bowden and Exley geared up and swam together through "El Pasaje" and into Zacaton. The pre-dive mood was positive and optimistic. The men began their descent at approximately 9:50 a.m. central standard time. Bowden dove to 925 feet and would spend nine+ hours decompressing. Exley, for reasons we will probably never know, failed to return from his dive. He had reached a maximum depth of 906 feet.

At about the same time that Exley entered the water that morning, Bret Gilliam was in California attending a Board of Directors meeting of the National Association of Underwater Instructors (NAUI). He had been elected Chairman of the Board only moments before when a phone message was relayed to him in the meeting. The caller explained that Exley, his friend and fellow NAUI member, was missing and presumed lost in Zacaton.

"I was stunned and speechless with the loss. It just didn't seem possible to me that Sheck would not be coming back," Gilliam reflects. *"Of all the divers I'd worked with on deep projects over nearly two decades, Sheck was always the person whose opinion and perspective I most valued. I thought back to the reams of letters and notes we had exchanged over the years about dive plans, rigging, tables, and the analysis of fatalities of others we'd known. To hear that he was gone without a trace left me feeling like some part of me had been cut away. He was the most accomplished diver and technician I'd ever known."*

Jim Bowden provides this account of that final day with Exley as they prepared for the 1000-foot dive.

"The time between December and April had passed rapidly with preparations and planning consuming every day and night. In addition to three sub-500 ft. dives, I made over 30 dives in excess of 300 ffw. Some were done on air to acclimate and build up my narcosis tolerance. Many of these dives included skills testing at depth, primarily problem solving questions or tasks posed by a colleague on mix while I was on air. It was essential that I be comfortable with an equivalent narcosis depth (END) of 330 feet. My bottom mix of heliair (69.5 He, 24.1 N2, 6.4 O2) called for an END of about 300 feet at 1000 feet. The bottom would demand that and more. I made one dive to 411 ffw on air, a record on air in a cave, but it was soon eclipsed by Sheck with his dive to 420 ffw on April 4th two days before our attempt for the bottom."

"Now was the time to fish or cut bait. The final preparations were made and the first support team left camp to put down decompression oxygen and my DiveComm full-face mask that I planned to switch to at 20 feet. Shortly thereafter, we all left for the spring."

Present on the day of the dive was the team consisting of Exley, Bowden, Mary Ellen Eckhoff (Exley's ex-wife), Karen Hohle (Bowden's wife), Ann Kristovich, and Marcos Gary. Press representatives included a writer and photographer from *Sports Illustrated*, a photographer from *Destination Discovery*, and a television film crew from Channel 7 of Tampico. Also in attendance were the land owner and his family along with many of the local residents of the area.

Bowden continues, "Sheck and I geared up and swam through the 600 foot passage, El Pasaje de Tortuga Muerte to access our dive site. Surfacing in Zacaton, we swam slowly over to our descent lines. We commented on the beautiful day and wished each other luck. We separated at that time and went to our respective down lines. Time passed in silence as we calmed our breathing and focused our minds on what was ahead."

"After a time, I felt all was right and glanced over at Sheck. He seemed to sense my glance and nodded affirmation. I submerged and hesitated at 10 feet for a minute or so and then went into a free fall. I had planned a descent rate of one hundred feet per minute to 300 feet on air, then the same rate to 600 feet on heliair (50 He, 39.5 N2, 10.5 O2) and then switching to my bottom mix. I planned to slow my descent around 750 to 800 feet where I had first noticed the HPNS symptoms on my previous dive. All went according to plan. As I passed the 800-foot mark, I was conscious of very little tremor. I could just see Sheck's light in the distance. It was the last I saw of him."

However, at 900 feet Bowden was shocked to find that he had breathed far more gas volume than he had planned. His bottom mix cylinders contained barely more than 1000 psi. At that depth, his regulators could not deliver if the pressure dropped less than 500 psi. This was a big problem and Bowden had to deal with it quickly.

"I inflated my BCD wings and managed to stop my descent at 925 feet. I switched to the 80 cubic foot tank of bottom mix under my right arm and breathed that and then my travel mix back up to my first stop at 450 feet. By the time I got there they were both empty. To my horror, the regulator on my deep deco bottle free-flowed violently when I turned it on. It seemed to take a lifetime to shut it off again. I switched back to my back-mounted doubles to deal with the problem but I couldn't fix the regulator. The only solution was to open and close the valve with each breath. I had eight minutes of stops between 350 and 300 feet where my next bottle was hung."

Bowden could breathe easier when he made it to the fresh decom bottle with a properly functioning regulator. Now would come the really long decompression and the worry about oxygen toxicity and bends. Another switch to air at 260 feet would see him to 130 feet and a 30% oxygen nitrox mix. That's when he knew something was wrong with Exley.

"At 130 feet, I relaxed. Here I could clearly observe the line that Sheck used on descent. All of his stage bottles were still neatly packaged and unused. The sinking feeling in my heart was overcome by the confidence that he had gone deeper than I had and was probably still below me."

But on the surface, the support team already knew that Exley was in trouble. Ann Kristovich had watched the bubble paths of both men on the initial descent. Bowden's bubbles disappeared at two minutes and Exley's vanished a few seconds later as they both reached the deep ledge at 250 feet. Only one set of bubbles re-appeared after about 15 minutes and she couldn't be sure if they were Bowden's or Exley's. Kristovich exchanged uneasy glances with Bowden's wife, Karen Hohle. As planned, she then dived to meet Bowden at the 47-minute mark of the dive profile. She was relieved to find him but chilled to see Sheck's stage equipment still hanging with no sign of him. The grim awareness of the situation gripped the pair.

Meanwhile, Mary Ellen Eckhoff (one of the world's premier cave divers and Exley's ex-wife) was watching from the cliffs with no knowledge of the problem. She joined Hohle at the surface and was apprised of the scenario. Concerned but not panicked by the situation, she grabbed an extra decom bottle to take to Exley and swam down to encounter Bowden and Kristovich. Now her worst fears were becoming reality. She hastily scrawled on a slate, "I'm going to 250 to look for bubbles". Dropping over the deep ledge, she could find no sign of Sheck or any bubbles coming from the depths.

Hohle had scrambled into her gear and caught up with Eckhoff. "I met Mary Ellen at about 100 feet on her way back up. She was crying and her mask was messed up. She wanted to go back to the surface but I grabbed her gauge and saw that it read 278 feet. I just held her. We stayed down for more than thirty minutes to get through the decompression. It as a very lonely time."

Bowden was finally told that Sheck was lost as he reached his 60-foot stop. He felt himself grow numb from the loss and describes the remainder of his decompression as a mechanical exercise with little conscious thought. After a total of nearly ten hours, he surfaced but suffered a left shoulder DCS hit that then was treated with in-water therapy on the site. Bowden was now the first diver to successfully break the 900-foot barrier on self-contained scuba. His record depth of 925 ffw eclipsed Exley's old 881 mark.

There was no consideration given to mounting a body recovery for Sheck since it was accepted that the only man capable of effecting such a recovery was the man who was already down there. Three days later while hoisting up the remainder of the equipment, Exley's body was found. He had apparently drifted up from the deep cave passage and become entangled in the line. One of his tanks still had gas and his computer read 904 feet, suggesting that whatever trouble he had did not occur until about nine minutes into the dive.

The best educated guess would point to an HPNS incident. Exley had experienced a bad one in Africa that resulted in uncontrollable muscular spasms and multiple vision. This may have manifested again with more violent tremors that could have triggered an oxygen convulsion or simply made it impossible to negotiate gas switches as necessary. His death will remain a mystery and a tragic loss to the cave community.

As Sheck's last dive partner, Bowden shares his thoughts, "I've been angered by unkindness and idle speculation by arm chair quarterbacks. And I have been touched by those who seem to understand and genuinely express sympathy without the need to pull something out of my soul. Much has been written in praise of Sheck and more will come. Ultimately, he will represent even more to us as history and recognized as the pioneer he truly was."

"I first met Sheck in Mexico in 1988 when he was making his then world record dive to 780 feet in Mante. I drive up to the spring while he was still underwater in the cave. He was alone in that great system. His support staff of only three, Ned DeLoach, Sergio Zambrino, and Angel Soto were awaiting his return. In this egomaniacal discipline of cave diving it was refreshing to see a man accomplishing the impossible without fanfare and entourage that we see so often with far lesser endeavors. Sheck sought my friendship as I did his for the same reason: we were loners. He was the only one of the north Florida group

that respected my work. He did that with other explorers in all parts of the world. He was interested, humble and supportive of projects than many of "new age" cave divers didn't even know existed. We had a common bond, an obsession, a passion...our love of exploration."

"Exploration was a demanding mistress that got in the way of our relationships with others and I now could cause a lot of pain to those who loved us. We could spend most of day on a project without even talking to each other. Our personalities were direct opposites. He was the most disciplined man I have ever met with a brilliant calm intellect. On the other hand, I'm 52 years old, still get in fights, drink too much at times and competitive to a fault. Yet, we got along great. Karen and Ann have both said that we looked like little boys who found the greatest treasure on earth when we found that Zacaton was the ultimate world-class deep system. I do believe that we both were never more alive than in those moments of trial in virgin space."

"Mexico loved him. He truly respected their culture and ways. The rural poor of Mexico have a remarkable ability to judge courage, honesty, and sincerity. The only time I allowed myself to succumb to emotion during those days of our loss and the recovery was when I walked to the edge of Zacaton and saw the simple cross and flowers put there by the people of el Nacimiento and Higeron."

"Sheck met life head on, with few misconceptions. Only death deceived him, taking him by surprise. Project Zacaton will continue. There was never any question about it. I was quoted as saying it would be an insult to Sheck to shut it down. I found this system some five years ago and put it on hold to obtain the technical training and the support to make it possible. Sheck gave me that. I will miss him very much, but then we always dove alone anyway. Perhaps now he will be with me more than ever."

The Proyecto will continue its efforts in Mexico after a brief pause for the rainy season. Bowden feels certain after reaching 925 ffw that a dive to 1000 ffw is possible and he will pursue his plans to see the bottom of Zacaton. With the use of Heliair, the survey of the distant passage of the Nacimiento Santa Clara will be resumed. The exploratory team also plans to aggressively explore the magnificent deep caves of the Sierra Madre Oriental, including the Rio Choy, Rio Frio, Rio Sabinos, Nacimiento Mante, Nacimiento Huichihuayan, and many others.

MILESTONES IN TRANSITION

The evolution of deep diving in practice has undergone several distinct generations of popular view and perception. Initial deep diving experimentation by naval divers and early explorers such as Cousteau were linked to a common enough interest: a certain fascination with the unknown. Navy divers needed access to deeper depths for tactical operative purposes and scientist/explorers sought entry to deep-water zones for research and documentary applications. There was no stigma applied to deep diving per se; in fact, the element of danger and bravado summoned to challenge the unexplored abyss was greeted with a certain appreciative respect for these fledgling "aquanauts".

The initial penetrations to progressively deeper depths by free-swimming scuba divers quickly showed the severe limitations of these divers due to narcosis impairment. Early accounts by Cousteau and other team members relate romantic anecdotal accounts of narcosis so limiting as to preclude diving much below 150 feet. An examination of their methodology in deep diving sheds sufficient light to reveal serious flaws in dive planning that would never be tolerated by today's standards. But hindsight, of course, has the benefit of 20/20 vision in all circumstances. Dumas, Falco and Cousteau himself nonetheless continued with deep diving experiments in spite of several tragic deaths to associates.

It would be interesting to note at this point how the sport diving industry came to accept certain "axioms" about diving practice with little awareness of the true process of evolution that came to dictate some of our current "sacred cows". Most recreational diving instructors have all been schooled to accept the Navy recommendation of 60 foot per minute ascent rates and that the Navy tables were "holy writ". Only in recent years has closer examination shown the benefits of slower ascents that are now almost universally advocated. How then did the 60-ft./min. rate come into being? Like so many things that we would like to believe resulted from years of research by learned physiologists in nice white lab coats while surrounded by reams of theoretical and field testing data, the ascent rate was derived by a process a little less complex.

In a workshop meeting in the fifties, a group of various delegates from the Navy met to standardize certain practices for Navy divers. One item of heated discussion centered on ascent rates. The scuba diving faction wanted a 100-ft./min. rate; but the hardhat diver faction subscribed to a 25-ft./min. rate. Actually, to be more accurate the tenders for the hardhat divers wanted the slower rate and for good reason: they were responsible for winching these exceedingly heavy monsters on their stages back aboard ships or diving platforms. Many dive operations of this era still used manual winches to recover divers and the exertion required in such a hoist was considerable. Why do you think Popeye had such well-developed forearms? At any rate, it was abundantly clear that the hard hat divers could not be winched aboard at anything close to 100 feet per minute, so a compromise was reached by all parties at 60 feet per minute and it was blindly adhered to by all who followed for over thirty years.

Then there is the supposed depth limit of 130 feet for scuba diving. At a recent international conference on diving safety held in 1991, representatives of the national scuba certification agencies were queried on the basis for the 130-foot rule. Although most admitted that they did not know its origin, all held true to the precept that it was a Navy recommendation and therefore it must be right.

Once again, the Navy reference was subjected to misinterpretation by well-meaning educators. In actual practice the Navy had found that it was not productive to assign a diver to a task deeper that 130 feet since he would have an allowable bottom time of only 10 minutes; scarcely enough time to evaluate an assignment and accomplish any useful work. If he was to do a job effectively this deep it was more efficient to equip him with a surface supplied gas source so he could complete the project and then manage his decompression. Somehow along the way, the sport diving industry misapplied the Navy's proprietary working diver recommendation into a sweeping condemnation of any diving below 130 feet. This has come back to haunt the certification agencies in two ways: 1) Since the depth "limit" is almost universally ignored by all but entry level divers, a significant segment of the sport diving population has been effectively forced into "outlaw" diving profiles and consistently deny deep diving thus distorting actual diving trends and statistics, 2) Increasingly more diving personal injury and wrongful death lawsuits are litigated on arguments of negligence based solely on the depth of the dive exceeding the "safe" limit of 130 feet.

THE ANDREA DORIA EXPEDITIONS

Deep diving has been practiced outside the traditional commercial and Navy communities for almost forty years. In 1956, Peter Gimbel called a *Life* magazine editor to see if they would be interested in underwater photos of the ocean liner *Andrea Doria* which sunk off Nantucket Shoals following a collision with another ship only the day before. Assured that *Life* would purchase any such photos that Gimbel could produce, he and Joseph Fox hired a plane and flew to Nantucket where, after considerable difficulty, they were able to charter a local boat to go out to the wreck site.

The wreck was a massive ship, 700 feet in length and displacing almost 30,000 tons. She settled on her starboard side in approximately 250 feet of water. This afforded access to her port side beginning in 160 feet. Gimbel used the standard of equipment of his day: double tanks and a double hose regulator with no cylinder pressure gauges. Rubber suits over woolen underwear served as thermal protection in the cool northeast water. Less than 24 hours after her fatal plunge, the ship was still gleaming white as the two divers dropped onto her port rail. Gimbel began working with a housed 35mm Leica camera and had fired off only eight frames before Fox suffered dramatic incapacitation from carbon dioxide build-up. Reacting to his signal, Gimbel abandoned his photography efforts and assisted his stricken buddy to the surface where he swiftly recovered. His dive had not been in vain however; the black and white Tri-X film pushed to 1000 ASA by the lab yielded usable shots and Gimbel had his exclusive with *Life*. Thus was born a lifelong passion for him with the *Doria*.

Gimbel would return to the site repeatedly over the years. At the age of 52 in 1981 he mounted an expedition to recover the Bank of Rome safe from the First Class foyer. With 33 days on site, and use of both scuba and saturation divers he successfully recovered the prize. After depositing the safe for dramatic effect in the shark tank of the New York Aquarium it remained for three years. On August 16, 1984 the safe was finally opened before an expectant international television audience. Much speculation had centered on the safe's contents. Would it contain the riches in personal valuables, jewelry and gold that had fueled rumors for twenty-five years? Gimbel's worst nightmare was that it might simply be empty. But as the door swung open finally, the safe revealed a mother lode of U.S. and Italian currency still neatly bundled in rubber bands. Although no gold bars were found, Gimbel's monetary haul had considerable souvenir value. The thousands of bills, each etched by the sea's destructive influence, were marketed encased in plastic mounts with certificates of authenticity. The proceeds would not cover the $1.5 million expedition cost but to Gimbel the reward was adequate. He had accomplished what scores of others had attempted in vain. He died three years later.

The fascination with the *Doria* has tempted divers since her sinking. Numerous books and films have been devoted to the subject. In 1964, the team of George Merchant, John Grich, Paul Heckart and Dennis Morse accomplished what one author described as "one of the most incredible feats of underwater salvage ever accomplished on scuba. Their goal was to recover the life-sized bronze statue of Admiral Andrea Doria from his stance in the First Class Lounge." Dan Turner, captain of their salvage vessel *Top Cat*, carefully planned out the project while intensely studying the *Doria*'s blueprints. He wanted to enter the hull via the Promenade Deck to gain access from directly above the alcove encircling the statue. The divers made judicious use of explosives to blast away the glass weather shielding and metal framework to penetrate the interior. Careful to remove the blasted wreckage at each stage of the salvage so as to not damage the statue, they eventually established an entrance opening almost eight feet wide and five feet high.

At 210 feet, they found Admiral Doria still holding court to the silent ship.

They rigged slings to prevent the statue from falling and then commenced on the laborious job of hack-sawing by hand through the legs of the old boy to free him from his pedestal. The four-man dive team worked in shifts on compressed air for several days incurring then unheard of decompression by divers in the open ocean. At one point, the team exhausted their supply of hacksaw blades from the backbreaking work and operations had to be suspended while *Top Cat* steamed over to the Nantucket Lightship to beg replacements. Thus re-supplied the cycle of diver rotation began anew and finally Admiral Doria was freed from his premature watery tomb. Only his feet remained behind.

Weather conditions had so deteriorated by this time that Turner elected to retrieve his dive team without in-water decompression and use the ship's chamber for surface decompression. In spite of the heaving seas, the statue was winched aboard unharmed and eventually found a home in the Sea Garden Hotel in Pompano Beach, Florida. One of the expedition investors, Glenn Garvin, had recently purchased the property and had a special platform built for the bronze relic to preside over a magnificent banquet room seating four hundred people. It was appropriately named the Andrea Doria Room. The Admiral seems happy in his current residence and his amputated feet still adorn the original pedestal 210 feet deep on the wreck.

Four years later, Italian film producer/director Bruno Vailati arrived on the scene to shoot the classic *Fate of the Andrea Doria* with a crew including a young Al Giddings employed as a still photographer and backup movie cameraman. This was the last film team to observe the magnificent navigational bridge that collapsed into the sand shortly thereafter. Vailati's production featured panoramic footage of the entire wreck for the first time and chronicled the reclaiming of the ship by the ocean's inhabitants. Giddings' relation of that experience notes, "She is a city once again, more populated now by ten thousand times than during her brief life as a great ocean liner. Sea anemones grow from her rails by the scores, and huge schools of fish of every type swim down her teak decked passageways."

The first serious interest in the wreck by sport divers was organized by Michael de Camp during the summer of 1966. He and a group of other dedicated adventurers shared the cost of chartering the *Viking Starlight* for the inaugural assault on the *Doria*. One year later, northeast deep diving pioneer John Dudas entered the bridge station and recovered the binnacle cover and ship's magnetic compass. History was set the same trip when Evelyn Bartram became the first woman to dive the *Doria*. She would become Dudas' wife shortly in the future.

The *Doria* seemed to inspire creativity in would-be salvors and in 1968 the first saturation expedition was mounted by Alan Krasberg and Nick Zinkowski. Their motivation, as usual, was capture of the fabled chief purser's safe and its valued contents. By use of an underwater habitat, divers could go into saturation and continue working on the wreck virtually indefinitely with one large decompression schedule assumed when the job was completed. This was not a new concept but this application for "treasure salvage" was. The habitat itself was decidedly new; christened the *Early Bird*, it was constructed not of steel but wood! Its builders theorized that its building material would provide more insulation and make occupancy more comfortable. Obviously comfort, like beauty, must be in the eye of the beholder since the habitat was only ten feet long and four and a half feet square. This would be the first use of HELIOX as a saturation breathing gas for wreck salvage. Partially funded by MGM, the project would serve as a theme for a documentary film.

Krasber and Zinkowski were adept at securing an international all-star cast as crew. Giddings was brought in a chief cinematographer, significantly upgrading his status from that of Vailati's filming expedition three months earlier. He enlisted as assistants Chuck Nicklin, a California dive store owner, and Jack McKenney, then an editor with *Skin Diver* Magazine. All three men would go on to fame as celebrated film makers, McKenney with his *Dive to Adventure* series while Giddings and Nicklin would go big-time with such Hollywood features as *The Deep* and *The Abyss*. Now however, the compensation was not much over meal money. Elgin Ciampi was engaged by *Life* to operate an experimental multi-camera "sled" designed by Demitri Rebikoff that would function as a photo-mapping transect. Rounding out the distinguished ensemble was breath-hold diving champion Jacques Mayol of France.

Incredibly, with all this talent, virtually every thing that could go wrong did… in spades. Weather held them at the dock until October after construction delays on *Early Bird* forced them to miss the fair summer sea conditions. Following an abortive attempt to anchor and rough conditions that almost sank the habitat, their support vessel *Atlantic Twin* gave up and headed for the shelter of Martha's Vineyard. With more settled conditions the next day they steamed back to the site but gear failure in the rigging process so hopelessly fouled the support lines to the habitat that it was recovered on board just in time for yet another storm to blow in and force them to heave-to for three straight days.

The dive and camera crew utilized mixed gas which greatly improved efficiency when they were finally able to resume operations after the storm. Oxygen decompression was employed in one its earliest applications by non-military and non-commercial divers. Following a productive day of filming, yet another setback showed up in the form of a double bends accident involving Ciampi and Mayol. Ciampi exhausted his gas supply while wrestling with a malfunctioning camera sled known as a Pegasus. He floated to the surface unconscious following an attempted free ascent and was rescued. Mayol, who was operating the other Pegasus unit, attempted to save both sleds by clipping them together but was unsuccessful and both sank. He arrived on the surface with skipped decompression and was loaded in the ship's chamber with the apparently lifeless Ciampi. Luckily, both responded to recompression therapy.

A combination of more bad weather and continued problems with rigging *Early Bird* to the wreck led to the expedition's backers finally throwing in the towel.

Not to be outdone, a new expedition was put together in 1973 by Don Rodocker and Chris DeLucchi, two ex-navy divers. They called their company Saturations Systems and intended to take up where the trouble-plagued *Early Bird* project left off. Equipped with a custom designed habitat called *Mother*, they joined the race for the *Doria*'s safe whose legend now had grown to be reputedly worth over five million dollars! Bob Hollis, founder and CEO of diving manufacturer Oceanic Products, came in as a financial partner with machinist Jack Clark. McKenney returned to direct photography along with Bernie Campoli and Tim Kelly.

Mother was far more sophisticated than *Early Bird* and substantially larger. She also could be handled in a less forgiving seaway and had the capability to operate independent of surface support for up to a week if the diving ship were to be blown off the site. Once again though, the *Doria* seemed to haunt these intrepid professionals in much the same manner as their predecessors.

Initially blown off the wreck, they successfully set up their mooring a day later only to realize they were made fast to the after section of the wreck and would have to start from scratch and re-rig further forward on the main bridge wing. After the time consuming and difficult task of relocating, the habitat severed a main power umbilical with Rodocker and DeLucchi already in saturation. The decision was made to hoist

Mother aboard and return to port for repairs. Upon reaching the dock, the saturated divers were nearly killed when the crane unloading the habitat accidentally dropped them on the pier. Against all odds, *Mother*'s hatch seals held and the decompression continued without further mishap.

Finally on August 8th, a permanent mooring was established in the proper section of the wreck. But after eight days in saturation by Rodocker, DeLucchi and eventually Hollis they discovered that the sea's deterioration to the ship's interior had created an impassable mass of wreckage blocking any reasonable path to the safe. Once again, the *Doria* refused to yield her treasure.

Gimbel's 1981 expedition would capitalize on the earlier work of *Mother's* team. Massive holes were cut into the hull and superstructure by Rodocker and DeLucchi; Gimbel's team, armed with an even more refined habitat and support ship, leap-frogged on these penetrations to eventually reach the safe. But like a reluctant bride, the honeymoon was disappointing. Gimbel spent almost two million dollars on this expedition and recovered only a fraction of his costs.

FIRST LADY ON THE DORIA: EVIE DUDAS

In 1964, Evelyn "Evie" Dudas took up scuba diving with less than an ideal motivation. She figured that it gave her the inside shot in winning the attention of a boyfriend away from a non-diving competitor. "I was nineteen then and he was an avid diver. He had another girlfriend who didn't dive, so I figured my ace in the hole was to learn all I could about the sport. My first dive was in Richland Quarry in Pennsylvania and I was so hooked I dove in another quarry the same day. I continued diving all over and even visited Canada to dive the shipwrecks up there. I broke up with the boyfriend, but had discovered a new calling: diving! I've been involved ever since."

Only three years after her first plunge into that dark quarry, she would become the first woman to ever dive the infamous wreck of the luxury liner *Andrea Doria* sunk in 1956 in a collision with another ship. Only a handful of men had ever visited the site by 1967 and she had to overcome superstition and other obstacles placed in her way to gain acceptance. "In working up to the *Doria,* I dove all the serious New Jersey wrecks. On most of these dives I was the only girl aboard. In the beginning there was a strong male chauvinist reaction to my presence. But after I proved I could keep up with all of them and outdive some of them, I was heartily accepted. Especially by a guy named John Dudas."

John would be her partner on three historic dives to the *Doria*. A group of twelve divers and an all-male crew voted her a spot aboard the *Viking Starlite* for the expedition. "Captain Paul Forsberg headed the boat into three foot seas on a cold June morning that summer in 1967. We had plans to anchor over the wreck for three days and two nights. It's about 110 miles from Montauk Point, Long Island and 60 miles due south of Nantucket. Late that same day we zeroed in on the *Doria* and our first team of divers attached the anchor line to the stern wing railing of the wreck."

"As I toppled from the warm, safe confines of the dive boat into the dark, icy Atlantic, neither storms, sharks, currents nor the bends were going to prevent me from fulfilling my *Doria* dream. I followed John down the line that terminated on the most magnificent wreck I had ever set eyes on. In the fifty foot visibility the hull looked like an enormous freight train disappearing into the misty sea. Surprisingly, the whiteness of the upper decks gleamed brightly through the haze, sort of inviting us to explore them."

"My third dive on the last day was the most exciting. I was with John again and he was after the binnacle cover to the ship's compass, still intact in the wheelhouse. He had spotted it the day before and he rousted me out at six a.m. to go after the darn thing. The visibility was good but the water seemed colder, forty degrees or less." After making their descent John occupied himself with the binnacle at 205 feet while Evie salvaged some brass door handles from the officer's duty lounge and chart room. The wreck site is plagued by changing currents, rapid weather switches and the hazards of ocean going ships passing over the area. Suddenly she was overcome by apprehension and cold. An unknown voice told her it was time to go. She made her way out of the wreck's interior to rendezvous with John.

"I needed John and I was ready to go. But he let his temper get the best of him and was trying to wrench the whole binnacle from its mooring. Somehow he regained his cool, gave the cover a twist and lifted it right off. There, beneath the cover, lay the compass that guided the 30,000-ton liner on a collision course with the *Stockholm* eleven years earlier. This was the most prized artifact and we thought other divers must have salvaged it long before us. I watched as John ripped it from its mounting."

"The cross currents fiercely swayed the unruly anchor line as we held on for dear life throughout the decompression stops. Fifteen minutes after we boarded the *Viking Starlite* the one and one half inch thick nylon line snapped! I guess my timing was perfect. We bade farewell to the *Andrea Doria* as storm warnings swept over her gravesite. We had our souvenirs and I had fulfilled my dream."

John and Evie were married in 1970 and produced four children, all active divers. Widowed in 1982, Evie remains totally immersed in diving as a dive store owner in West Chester, Pennsylvania. Her business Dudas' Diving Duds is one of the premier pro facilities on the East Coast.

THE MIXED GAS PIONEERS

Paving the way for mixed gas users today, were early experimenters such as Arne Zetterstrom and Hannes Keller who conducted some of the most daring open water dives with then theoretical gases for divers. Zetterstrom, a Swedish engineer, was fascinated with diving and sought to extend the working depths of divers by manipulating the oxygen content of a gas mixture and replacing the narcotic nitrogen with a more "workable" inert gas. Alternatives such as helium and neon were in such short supply as to be virtually unattainable in Sweden in the early 1940's so Zetterstrom focused on hydrogen as a replacement. It had favorable properties with respect to density, viscosity and narcotic potency but had the major disadvantage of forming oxy-hydrogen gas that is highly explosive if mixed with oxygen percentages in excess of 4%.

He was faced with several operational problems from the outset:

1. A 4% O_2 percentage would not support human life underwater until approaching the 100 fsw depth range.
2. Therefore a "travel" gas mix would need to be utilized to allow the diver to safely travel through the surface to 100 fsw range and back.
3. Now the curve ball… regular air as a travel mix could be used to 100 fsw and satisfy the oxygen requirements. However, if the oxygen-hydrogen mixture were to come into contact with a normoxic air mix, it would create oxy-hydrogen gas and, at least theoretically, the diver would explode. So a third mix, a transition gas mixture, would be necessary to protect the diver.

Zetterstrom decided to use one of the earliest NITROX blends as his transition mix: a 4% oxygen and 96% nitrogen mixture. This would allow a safe bridge between the O_2/H_2 "bottom mix". The diver would switch to the NITROX cylinder at 100 fsw and breathe for a period sufficient to flush out the higher O_2 percentage and then switch again to the "bottom mix". This cycle would be repeated during ascent.

It should be noted that since Zetterstrom manufactured his own hydrogen aboard ship at sea by breaking down ammonia to yield 75% H_2 and 25% N_2, his final mix was actually a TRIMIX of 4% O_2, 24% N_2 and 72% H_2. This was one of the earliest uses of TRIMIX; nitrogen in such reduced percentages was not a narcotic factor. In his experimental dives to 130 fsw he encountered no difficulties but was unpleasantly surprised to discover the highly conductive thermal properties of hydrogen and became uncomfortably cold quickly. Also, the light density of hydrogen, like helium, produced "Donald Duck" speech making voice communications with his surface tenders virtually impossible.

His second attempt would be conducted much deeper. The 300 fsw barrier was largely regarded as the limit of practical diver performance, so deliberately he would test his mixture at 360 fsw. Lowered on a wooden stage by a winch from the stern of his support ship *Belos*, he negotiated his mixture switches flawlessly and reached his planned depth where he reported "slight breathing resistance and the narcotic effect practically nil". His dive was regarded as a huge success with implications for commercial applications and for submarine rescue operations.

On August 7th, 1945, Zetterstrom planned a monumental dive to 500 fsw for the first time, far in excess of any dives successfully attained at that point by any method. Tragically, a breakdown in communications within his surface support team led to disaster.

Once again, he employed the diving stage to control his descent and ascent with prearranged signals and time allotments for his mixture switches and bottom time. All went well on the descent and he reached 500 fsw without mishap. He signaled the surface that he was well and the ascent phase was initiated in accordance with his pre-planned schedule. He was winched up to 166 fsw to begin his decompression when all hell broke loose. He had rigged the stage platform not only with a lifting cable but also with two lines on either side to counteract any effects of current or tide. Somehow the tender handling the line to the bow of the ship misunderstood his instructions and winched his end of the platform all the way to within thirty feet of the surface. The stern tenders held steady with the intention of leaving Zetterstrom at 166 fsw. An impossible angle of tilt resulted along with rapid decompression. This resulted in the diver's inability to negotiate gas mixture switches or to conduct normal decompression. The 4% O_2 mix was insufficient to maintain proper oxygenation and Zetterstrom died due to hypoxia and severe embolism. He had dramatically demonstrated the practicality of his revolutionary gas mixes and shattered the depth record only to fall victim to the ineptitude of his surface support crew.

Hannes Keller began experimental dives in 1959 that would ultimately more than double the depths of Zetterstrom but again with fatal consequences to dive team members. Keller, a Swiss mathematician, joined forces with noted physiologist Albert Buhlmann to explore the highly controversial elements of accelerated decompression in conjunction with helium and oxygen mixtures (HELIOX). Both men could see the financial gain to be made by refining a system to place divers in working situations at incredible depths and bring them back to the surface without unreasonable delays due to decompression obligations. Much of their research was conducted cloaked in secrecy.

Working with a hyperbaric chamber capable of simulating 1500 fsw in November of 1960, Keller prepared for the first practical test of his new gas mixes and decompression schedules. This was to be a dual dive: Keller in the lower "wet" chamber and a team of French doctors in the upper "dry" chamber. Keller, equipped with a battery of diving equipment and varied cylinders for his mixes would dive alone to a simulated depth of 830 fsw! This was beyond conception even to theoreticians at this time. The French team would be exposed to a pressure equivalent to 200 fsw. Keller's rapid compression to twenty-five atmospheres was accomplished in only ten minutes and the consensus opinion of outside observers was that he could not survive such an exposure. However, Buhlmann was in voice contact with him and reported him well at the bottom depth.

An equally rapid decompression to the 200 fsw level of the French team was conducted and Keller opened the connecting hatch to join the doctors in the "dry" chamber. Removing his gear and drying off, he then entered the access lock six minutes later. Following only 30 minutes more decompression, he emerged at the surface! By contrast, the French team exposed to only a maximum of 200 fsw would require twice as much decompression time under their conventional tables. Keller had been over four times deeper.

He would not stop there. The second pivotal dive took place in actual open water conditions in Lago Maggiore and, this time incredibly, he took along a *Life* magazine reporter named Kenneth McLeish. They would reach 730 fsw while being lowered on a similar platform stage as utilized by Zetterstrom. This time the topside commands were personally supervised by Buhlmann to avoid any possible problems in operational execution. The dive required four mixes to be employed and broke the in-water record of 600 fsw held then by British Royal Navy diver George Wookey. In startling contrast to Wookey's decompression time of twelve hours, Keller and McLeish completed their decompression in less than 45 minutes. Keller had proved the validity of his decompression theory and McLeish had forever set a new standard in "on scene" reporting. It's hard to imagine one of today's blow-dried news anchors donning a dive suit to report the story from the sea floor.

The Lago Maggiore dive finally prompted the major financial support Keller and Buhlmann so desperately needed. Funding was now supplied by a group of U.S. corporations including Shell Oil, General Motors and the Navy. Keller announced his goal to reach the average limit of the continental shelf and thus open up the exploration of mining raw mineral deposits and food resources previously unreachable. This 1000 fsw dive was scheduled off Catalina Island in southern California.

A custom built diving decompression chamber named *Atlantis* was constructed capable of carrying two occupants to the sea floor over 30 atmospheres down. It was fitted with two chambers and a connecting lock to allow Keller to exit *Atlantis* and then re-enter and conduct his decompression in the upper chamber. With an ever-mindful eye towards the international press, Keller once again chose a journalist to accompany him. Peter Small, a British newspaperman, was only an amateur diver but had obtained a commission assignment for a substantial fee on the stipulation that he personally write the article.

Hans Hass was a personal friend of Small's and writes of his misgivings about the upcoming dive in *Men Beneath The Sea* (1973): "Peter Small had been married only shortly before this, and his wife, Mary, as attractive as she was energetic, was vital to his resolve, or so it seemed to us. From a long conversation with Peter I got the feeling that deep down in his heart he was undertaking more than he really wanted. I don't mean by this that he was afraid, but that he lacked the freedom from doubt, the confidence of Hannes Keller. Various circumstances soon deprived him of his freedom of choice (the newspaper commission among them). Mary saw in him a hero… there was no escape… Somehow I felt uneasy. Peter was a true Englishman, and did not betray his feelings, but I knew him and all divers well enough to understand him."

Several practice dives were conducted working up to the 1000 fsw exposure and in the process two bends hits were sustained, one on Hermann Heberlein and one on Peter Small only two days prior to the planned primary dive. Keller and Small had taken *Atlantis* to a depth of 330 fsw and exited to spend over an hour outside on the bottom. Small had a minor hit in his elbow after surfacing and was recompressed. On Monday, December 3, 1962 all was finally ready and the support ship *Eureka* was moved into position where the sea floor was exactly 1000 feet deep. An umbilical hose linked *Atlantis* with the ship down to 330 feet to supply gases and pressurization to the chamber. Beyond this depth the divers were on their own connected only via the steel lifting hawser. Keller had installed back-up cylinders in *Atlantis* to provide extra breathing gas if needed. Each diver was equipped with a back mounted rig capable of providing 15 minutes time. It could be replenished by filling off the back-up cylinders. Unfortunately, it was discovered that the back-up units were leaking and Keller was forced into a difficult decision heavily influenced by the financial pressures of corporate endorsement and the desire to still maintain the secrecy of his mixes and decompression schedules.

Keller related to Hass, "Before the attempt, this was the situation: barely enough gas in the equipment carried on the back; on the other hand, the team in top form, weather perfect. Personally, a strong fear that it might be all called off. Knowing that one never has perfect conditions, an attempt under perfect starting conditions never happens. Never. There are only adequate starting conditions… Well then, I decided to make the attempt."

His goal was to briefly swim out of the chamber and plant the Swiss and American flags on the bottom. He determined that his primary gas units would allow him a sufficient safety margin to exit the *Atlantis* and return. Upon reaching the planned depth, the divers opened the exit hatch and Keller dropped the short distance to the bottom. But the flags became tangled in his breathing apparatus and it took him over two minutes to free himself and drop them. After he and Small successfully closed the hatch he was exhausted. At this point he should have refilled their breathing gear from the back-up cylinders but felt himself passing out. He was just able to activate the compressed air vent to flush the knee-deep water from the tiny chamber before losing consciousness.

The remote television cameras linked the surface crew with the developments on the bottom and they immediately instructed Small to remove his mask and breathe the air atmosphere. This would probably result in his unconsciousness as well but with Keller unable to operate the inside gas selections during ascent, it was felt that Small was better handled in this manner. But Small froze in horror and continued to breathe the deep mix and collapsed shortly thereafter out of camera view.

The tenders quickly raised *Atlantis* to 330 feet where divers were sent down to re-connect the umbilical. But at the 200 fsw level, the chamber proved to be leaking and could not be raised without risking explosive decompression to the occupants. Dick Anderson, a professional California diver, and Chris Whittaker, an English friend of Small, went down to ascertain the problem but could not locate the source of the leak. To Anderson it seemed that the chamber had solved its problems and the two returned to the surface. Whittaker was not nearly the experienced pro that Anderson was and had difficulty on the ascent with this safety vest. He arrived on the ship with a profuse amount of blood in his mask and thoroughly worn out. The surface crew informed them that the chamber was still leaking.

Since they were the only two safety divers, Anderson knew he would have to go back down but preferred to go alone.

"The boy was not very strong, and rather exhausted. He undid his weight belt and took it over his arm. I nodded to him. In an emergency, he could drop the belt and would then float to the surface. We swam down again. On top of the chamber I signaled to Chris to stay there and wait. I swam down again to the hatch. I had more than enough air and had a good look around... The cover was firmly attached but when I looked very closely I discovered a small crack in it. Something small was stuck there. I tried to get at it with my knife. Then I simply propped myself on the ladder and pressed myself upwards with my back as hard as I could. I did this for quite a while. Finally the hatch appeared to be sealed. When I swam up… Chris had disappeared. I thought he must have surfaced already since I couldn't see him anywhere. When I got to the top, they asked me where Chris Whittaker was…"

Whittaker was never found. The *Atlantis* was hoisted aboard and Keller regained consciousness and hastened to cut Small from his dive suit and examine him. He reported to Buhlmann that he was alive. Later he came around and said he was thirsty. Keller got him something to drink while Small briefly spoke to Buhlmann on the phone. He then went to sleep seemingly OK. However, when Keller checked his pulse later he discovered that Small had died. He was stunned at Small's death. Keller was completely fine. The double fatality cast his remarkable achievement in shadow.

Hillary Hauser, Dick Anderson's ex–wife, notes in her book *Call To Adventure*: "The Keller dive was an awful paradox. It was a success because one man made a 1000-foot dive and lived, proving that the mysterious mixture of gases had worked. It also was a disaster because of the deaths involved. No one knew whether to cheer or boo. The effect was the same as if Neil Armstrong had landed on the moon and lived, while fellow astronaut Buzz Aldrin had not made it back to Earth. In that case, would the moon landing have been considered a success or failure?"

Hass speculates that Keller's determination and confidence insured his survival while the less experienced and less motivated Small succumbed. Hass felt that had Dick Anderson been Keller's diving partner no lives would have been lost. With the benefit of hindsight, Keller would have been wise to ensure a more professional companion but Small had performed satisfactorily on the practice runs. Keller remained shaken but undaunted and continues today with consulting work in varying fields of diving and computer technologies. His vision of man's ability to work in extreme depths would provide the basis for commercial and naval systems that followed.

THE HABITAT EVOLUTIONS

That same year saw the introduction of the first significant advances in man's attempts to actually live in the ocean. Habitat and submersible pioneer Ed Link launched two short duration, but important projects back to back in August and September of 1962. Using himself as a guinea pig in the first project nicknamed *Trial Link*, he spent a cramped eight hours at 60 fsw in a tiny 11'x3' cylinder in the Mediterranean. Robert Stenuit followed him the following month in the same cylinder now called *Man-in-the-Sea*; this time for two hours at 200 fsw breathing HELIOX. On the heels of Stenuit's dive, came the first of Jacques Cousteau's *Conshelf* missions with two divers spending a week at 35 fsw off Marseilles. Much as the "space race" was heating up, so it seemed the race for advances in underwater saturation habitats moved forward.

In 1963, Cousteau followed up dramatically with *Conshelf II* in which seven "aquanauts" lived at 36 fsw on the ocean floor of the Red Sea for a month! During this same mission, Raymond Kientzy and Andre Portelatine spent a week in a specially staged mini-habitat called *Deep Cabin* at 90 fsw allowing them "excursion" dives with virtually no decompression to as deep as 360 feet.

In 1964, Link sponsored his *Man-in-the-Sea II* mission off the Bahamas and the U.S. Navy deployed *Sea Lab I* near Bermuda. A plethora of progressively deeper and longer saturation projects followed including the two-month mission of *Tektite* in the Virgin Islands in the late sixties. *Tektite* was utilized for multiple missions and in 1971 marked the first all female aquanaut team led by Dr. Sylvia Earle, later chief scientist for NOAA. Link also produced the venerable *Hydrolab* habitat that began operation in 1966 and into the mid-1980's before being retired to the Smithsonian Institution in Washington D.C. During its operational life it provided an underwater home to literally hundreds of scientists and researchers at its sites in Florida, the Bahamas and finally St. Croix in the Virgin Islands. Ultimately *Hydrolab* was replaced with the massive *Aquarius* habitat later relocated to a site in the Florida Keys. The saturation habitat fascination tapered off in the mid-1970s and now only a handful of projects remain in existence.

Tragically, Ed Link, one of diving's true technical innovators, would suffer the loss of his son while a team member in *Sea-Link*, a deep diving submersible of his design. In the summer of 1973 during a project sponsored by the Smithsonian off Key West, Florida, the sub became entangled in a cable from a wreck they were exploring. The scuttled destroyer *Fred T. Berry* fouled the *Sea Link* while she was attempting to pick up a fish trap at 351 fsw. All efforts by the sub's crew to extricate themselves proved to no avail. The submersible was configured with two chambers: A forward pilot's station for two crew and an after chamber capable of "locking-out" divers for exterior excursions. In the forward command station Bob Meek and Jock Menzies were surrounded by a large acrylic sphere and remarkably this would prove crucial to their survival. In the after compartment, Clay Link and Al Stover, an expert and highly experienced submariner, were encapsulated in highly thermally conductive aluminum.

Although the Navy dispatched its submarine rescue ship *Tringa* to the site, it was almost 12 hours before it finally was positioned over the trapped sub. A "roving diving bell" was airlifted from San Diego and delivered to the ship where it began its first descent the following morning at 9:20 a.m. At this point, the sub's occupants had been marooned for almost 24 hours. Swift currents in the area hampered the efforts to make contact with *Sea-Link* and time began to run out for the helpless four men. To conserve their precious on-board emergency air supply, the sub crew desperately spread baralyme in their compartments that would act to absorb CO_2 from the increasingly stale atmosphere. However, baralyme is ineffective below 70 degrees F. and in the aft compartment surrounded by the conductive aluminum the temperature rapidly plummeted. Stover and Link attempted to raise the baralyme temperature by spreading it over their exposed skin but this ceased to be effective after a time.

While the rescue crew furiously struggled to hook up with the sub, the trapped men finally turned to their emergency breathing system that supplied air to both compartments. The 36-hour ordeal held little hope that the rescue could be made before the air in the emergency cylinders was exhausted. Stover made a personal assessment of his situation with Link in the lock-out compartment and decided that they held far less chance of survival than Menzies and Meek in the pilot sphere.

In the ultimate heroic sacrifice to try to at least save his companions, Stover turned off the emergency air system for himself and Link. Both died before the sub was recovered but the other two men survived.

THE CAVE DIVERS

The earliest known use of scuba gear in United States caves was in January of 1953 by Frank DenBlykker and Charles McNabb to explore the then unknown depths of Florida's Silver Springs. The pair discovered that the Springs were only the entrance to a large cave system and on that first dive they stumbled onto the petrified remains of the elephant's ancient ancestor, the Mastodon. Cave diving was a little practiced sport in these embryonic days of scuba diving and only a handful of participants could be found struggling through the underbrush and down slippery paths to access the mesmerizing call of the dazzling, clear inland cave systems. Jack "Gil" Favor discovered many other of the now popular caves and was active in cave diving from the early fifties until the mid-sixties.

Sheck Exley made his first cave dive in 1966 shortly after his initial scuba training and was "hooked". Looking back at that period of his life in 1984 he recalls: *"Now, for better or for worse, my life was set; I was a cave diver. Sports heroes such as Tarkenton and Gehrig, and military genius Lawrence of Arabia were now replaced with Watts, Mount and Harper on the list of people I most admired. Hall Watts was the best deep cave diver, Tom Mount had the most cave dives and was the best published, and John Harper was simply the best, period."*

Mount began cave diving in 1962 after discharge from a hitch in the Navy as a UDT diver. His introduction was with Zuber Sink (later renamed Forty Fathom Sink) where he would make numerous dives to 240 ft. to bottom out the cave with Frank Martz, another early cave enthusiast. One of the most outstanding deep caves in Florida is Eagle's Nest. First discovered by Don Ledbetter in 1960, this cave is still unfolding as technology advances.

Ledbetter, along with others such as Lee Somers (later the head of the University of Michigan's diving program and a Ph.D.), explored the "Nest", then known as Lost Sink, to depths of 220 ffw. Later John Harper and Randy Hylton pushed on to 230 ffw with Mount and Martz laying permanent line in to a depth of 250 ffw in 1964. Hal Watts and members of his informal "diving club", the Forty Fathom Scubapro's, would reach 260 ffw while penetrating the upstream cave. In 1965, Mount and Martz set out to attempt to "wall out" (reach the end) of the Nest and with progressive pushes reached depths of 285 ffw. Joined by Jim Lockwood in 1969, they found a small passage that dropped to 300 fsw but did not appear to continue; Lockwood laid line in beyond that depth but ultimately encountered silt too thick to penetrate and that tunnel was abandoned.

The opening to the downstream cave was discovered by Mount and Martz in late 1968. This required the divers to negotiate a very tight restriction in the 280-290 ffw level before opening into a large and beautiful tunnel that is the major system of Eagle's Nest. In the years to follow, Lockwood and Jamie Stone would introduce the use of DPV's (Diver Propulsion Vehicles) and Exley would introduce the practice of multiple stage bottles to effect penetrations hundreds of feet beyond the early explorers. The lines laid by Lockwood and Exley would not be exceeded until the late 1980's when Jim King and Larry Green employed combinations of DPV's, staging and TRIMIX to reach 310 ffw for up to one hour and 18 minutes requiring seven hours of decompression.

In Mount's opinion (1991), "The Nest has been explored to the limits of open circuit technology. The use of rebreathers for further exploration is being investigated by King and Green and other members of the Deep Breathing Systems Team. We don't know the ultimate possible penetration or depth."

Possibly one of the deepest caves is popular Morrison Spring in the Florida Panhandle. This is marked by one of the largest and prettiest headpools at its entrance. In the early 1960's, Atlanta dive instructor Jack Faver, made extensive dives into the system and reported depths attained of 270-350 ffw. Martz and Mount attained 285 ffw in 1965. In 1968, teams led by Hal Watts, John Harper and Randy Hylton made it past an extremely narrow restriction at the 100 ffw level by removing their doubles and squeezing through to discover a fourth room extending to the 240 ffw level. Here they were stopped as the passage narrowed to only a small slit. Speculation that this later team missed a side passage taken by Faver and dive buddy George Krasle, stirs interest that the tunnels were not fully explored. Unfortunately, following the deaths of several divers, the local sheriff had enough and ordered the dynamiting of the passage leading to the third room thus sealing the passages forever.

Other deep cave penetrations included Jim Houtz's dive to 315 ffw into Nevada's Devil's Hole surrounded by Death Valley National Monument, and the Sheck Exley/Joe Prosser descent to 325 ffw in Mystery Sink in Orlando, Florida. Will Waters, Jamie Stone, Jim Lockwood and Exley would be among the first to lead pushes into the infamous Die Polder II sinkhole near Weekie Wachee with Dale Sweet reaching 360 ffw in 1980 on HELIOX accompanied by Lockwood on air. At the time of the dive Lockwood did not know that Sweet was using mixed gas, he had kept it a secret. It would be over 12 years before any extensions to the Lockwood/Sweet line would be laid; this time by Lamar English and Bill Gavin who were followed by Dustin Clesi and Jim King on TRIMIX and DPV's to a depth of 380 ffw. The group intends to return in the future to continue with rebreathers.

The father of "Blue Hole" diving has to be Dr. George Benjamin of Canada. He became fascinated with the Bahamian blue holes in the late 1960's after trips to the western island of Andros. Local legend and superstition kept natives and divers alike away from this mysterious phenomenon until Benjamin began diving in them. Due to the often-violent whirlpool effects near the entrance of the holes, it was said that they were occupied by evil spirits or the dreaded "lusca", an octopus-like monster that would drag fishermen and entire boats below the surface if they ventured too near. Benjamin quickly ascertained that the whirlpool effects were related to tidal cycles and was the first to develop dive plans designed around penetrations during the slack water period.

Since he took up blue hole cave diving at the not exactly youthful age of 50, he prudently decided that some younger assistants might be helpful in making the pushes into the labyrinth tunnels and an invitation was offered to veteran cave explorer Tom Mount to come over from Miami to help with the project. Mount proved an invaluable team member and led the way in Blue Hole #4 to discover the first stalactite formations in 1970.

Benjamin was something of an equipment inventor on his own, introducing the innovative "Benjamin Conversion" manifold that allowed the use of dual regulators on double tanks but provided the "isolation" capability in the event of a valve or regulator malfunction. The air from the "isolated" cylinder was channeled via his unique cross-over bar so that the second regulator/valve system could still access it. (Although Benjamin has largely been credited with the design, Ike Ikehara was actually the brains behind the manifold system).

But Mount arrived on the scene with other custom equipment like high intensity lights and specialized reels that he had not seen before. They were manufactured by Mount's close friend, Frank Martz, another veteran Florida cave diver. After several months of joint work by Benjamin's team and other American divers recruited by Mount including Ikehara, Sharee Pepper, Dick Williams, Jim Lockwood, Zidi Goldstein and Martz, they had pushed well beyond the limits of Benjamin's earlier projections. In the summer of 1970, an offshoot of Benjamin Cave (#4) was discovered by Tom and Ikehara who squeezed through a major restriction at 240 fsw to enter a totally unexplored passage.

Mount recalls: *"It was kind of a roller coaster tunnel that led down to a depth of 300 feet. Later Dick Williams and I placed permanent line in to 310 feet deep and ran into another restriction that we could just get through. At the end of this tunnel we reached a shaft that dropped out of sight. I leaned over at 330 fsw and shined my light straight down and we couldn't see the bottom. At this point, some thirty minutes had elapsed and narcosis was a complication coming back up the tunnel and through the restrictions. On the exit, I had to assist Dick from 290 feet up to 240 feet. He just sort of gave out; he could kick but there was nothing in his effort and he wasn't making any progress."*

In 1971, Mount and Martz discovered yet another deep tunnel with a major restriction beginning at 280 fsw but did not have the opportunity to explore it farther. In September, Martz arrived from Florida determined to push the new tunnel beyond the restriction. He enlisted Lockwood as his dive partner. From the beginning things didn't seem to go well. Martz seemed moody and out of sorts to his friends. Benjamin did not want the dive done since it conflicted with his work projects already scheduled and he considered it to be particularly hazardous. Mount was Martz's best friend and even found himself on the short end of an argument that day when he could never recall a strained word between them before.

Since Benjamin was paying the bills to support the mapping and survey of the Blue Holes, Mount explained that the work projects had to take priority. But Martz was insistent and Mount finally persuaded Benjamin to let the dive go forward. Lockwood and Martz set off together while Mount and Zidi Goldstein went into the north tunnel to extend the lines into that passage. Martz and Lockwood successfully negotiated the constricted passage and went on down to 300 fsw. While tying off a new reel, considerable silt was stirred up in the narrow area and Martz went through the restriction by himself. Lockwood waited, alone.

In conversation with Bret Gilliam in 1991, he reflects: *"Frank was a headstrong guy who was one of the country's top expert cave divers. When you dove with him you had to accept certain things like the fact that he was going to do whatever he felt on the dive. I was 21 then and Frank was 35. Frank and Tom were the kings, I looked up to them and would never have thought to question either of them underwater. When Frank went through that restriction, I never saw him again. I thought that he must have come by me in the silt-out and headed to the surface. I finally went through and found only a cut safety line dangling into a blue bottomless void, with my light shining from 325 feet deep I couldn't see any end to that shaft."*

Lockwood came back through and encountered Mount and Goldstein in the decompression area and briefly, by slate, conveyed that Martz had disappeared. Tom and Jim returned to the entrance of the south passage in the futile hope that Martz might appear but he was gone forever.

The loss of one of the U.S.'s top cave divers had a numbing effect on Mount and the rest of the Florida team. Two attempts were made by Mount and Lockwood to retrieve the body to no avail. In the notes from the police investigation report, Mount makes this statement: *"Frank Martz was probably one of the best cave divers in the world. He was a NAUI, PADI and NACD certified instructor. He was one of my best friends, and one of the people you think it is impossible for them to die diving. He had done more to develop safe cave diving equipment than anyone, and the cave diving world will miss him, his abilities, his excellent diving equipment and his devotion to the exploration of underwater caves."*

Tom may have been correct in his note that it was impossible to believe that Martz could die in a diving accident. All the team had noted his strange behavior in the time before the dive.

Sheck Exley remembers that period: *"The summer of 1971 was especially noteworthy in Florida. A tiny amoeba had infested the water of many of the lakes and ponds in central Florida. It had been reported only a couple of miles south of Eagle's Nest and I think it's reasonable to assume that this amoeba was there as well. Why so much fuss over a microbe? If the amoeba infects a swimmer or diver, as it did in Florida that year, it was 100% fatal. It caused encephalitis, swelling the human brain so that severe headaches are felt in the early stages, then comes high fever and death a few short weeks after the initial infection. How does it get into the brain? Through the nasal passages. Frank had spent countless hours decompressing with his nose in the water (with no mask) at Eagle's Nest. At Andros, divers soon noticed Frank acting strangely. He seemed moody and depressed, and was intent on doing dives that were especially dangerous."*

Lockwood may have been an unwitting buddy to a diver focused on a one-way dive. Mount has voiced the same speculation.

Exley concludes: *"A terminally ill cave diver with no close family ties could scarcely pick a better way to commit suicide: in one of the world's most spectacular underwater caves, at a depth deep enough to insure that his passing would be rendered painless by narcosis and make it very unlikely that his body would ever be found."*

The Great Blue Hole of Lighthouse Reef Atoll located some 70 miles off Belize harbored similar superstitions as the Bahamian blue holes. In 1971, the Cousteaus traveled with *Calypso* to explore its uncharted depths for the first time. Widely rumored to be "bottomless", stalactite formations were discovered at a depth of only 140 fsw and with the use of their diving submersible the Blue Hole was bottomed out at just over 600 fsw. Following this expedition, they continued on to the Bahamas to visit Benjamin and Mount in Andros to film the local blue holes they were mapping. Ironically, Jacques Cousteau almost was killed in #4 when he got off the line on the way out of the cave.

The Lucayan blue hole, called Ben's Cave, located on Grand Bahama Island ultimately proved to be one of the longest cave systems in the world. Sheck Exley would explore another even larger system in Belize on Caye Cawlker. After diving the Great Blue Hole and Ben's Cave in the early 1970's, Bret Gilliam searched in vain for similar formations in the Virgin Islands. But he did discover tunnels cut into the face of the steep north shore drop-off of St. Croix. These began at extreme depths, usually 330 fsw or deeper and penetrated nearly horizontally back into the wall face. Some had entrances as narrow as three feet that extended in more than 200 feet before widening sometimes into rooms that were impossible to measure. They were initially discovered by accident on deep wall dives and were extremely difficult to locate. Due the depths and equipment available in this era, the explorations of these mysterious tunnels were largely discontinued after a DPV failure in one push that almost killed him.

Additional Andros Blue Hole expeditions were undertaken in 1981 and in 1987 by Rob Palmer, Bill Stone and their associates. They succeeded in discovering numerous additional inland blue holes and explored them to depths of 310 fsw with the use of mixed gas and rebreathers. Their discoveries were of dramatic proportions yet they still did not achieve depths beyond those of Mount, Martz, Lockwood, Ikehara and Williams almost two decades before on compressed air.

Currently the fastest emerging technological advances in deep diving are coming from the cave diving fraternity. Individuals like Parker Turner (the Sullivan Connection), Wes Skiles and Bill Stone (the Wakulla project), Larry Green (recent Eagle's Nest penetrations) and Jim King with Dustin Clesi (Eagle's Nest and Die Polder II) are all on the leading edge of progress with mixed gas, DPV's and other developing equipment such as fully redundant rebreathers.

WOMEN DEEP DIVERS

In a diving niche that is already limited, there have been only a handful of women participants over the years. One of the earliest woman deep divers was Rosalia Zale Parry, who reached 209 fsw off Santa Monica, California in 1954. She enjoyed a long career in diving as an actress and stunt person in such series as Lloyd Bridges' popular hit *Sea Hunt.*

Well-known scientists Dr. Eugenie Clarke and Dr. Sylvia Earle pursued research projects in depths far in excess of many men divers during the 1960's. During this same period, Zidi Goldstein and Dr. Sharee Pepper at the University of Miami were involved with open water and blue hole deep diving missions that regularly had them in 300 feet plus depths.

Evelyn Dudas was the first woman to dive the *Andrea Doria* wreck in 1966. Given the harsh conditions and depth of that site, her accomplishment is particularly significant. Another trailblazer has been Mary Ellen Eckhoff, one of the top American cave divers, male or female, of the last twenty years. Since 1978, she has held all of the cave diving depth and penetration records for women in addition to sharing the record for overall penetration at Big Dismal in 1981. Her 5847-foot penetration with Sheck Exley and Clark Pitcairn was the world record that summer. She was also the fourth cave diver in the world to complete more than 1000 cave dives (Tom Mount, Exley and Paul DeLoach were the first), and was the second diver in the world to dive to 400 fsw in a cave (on mixed gas). She was the first female diver to ever dive to 300 fsw in a cave and has "unofficially" equaled the women's open water record of 345 fsw on July 4, 1982 off Grand Turk Island while diving with Exley.

Marty Dunwoody holds the officially recognized women's open water depth record of 345 fsw set December 21, 1988. She trained under Hal Watts methods and is now an active instructor with his Professional Scuba Association in Ocala, Florida. She continues a long line of Watts- trained record holders that date back to the 1960's.

Finally, the ultimate woman deep air diver has to be the late Ann Gunderson. During practice dives in working up to the 1971 record attempt in the Bahamas, she made over 40 dives below 400 fsw. Sheck Exley observed her on at least one successful drop to 420 fsw, and her dive buddy Jim Lockwood confirms that Ann made approximately 25 dives in this range. Although, Gunderson never attempted to claim the "shallower" dives in her pursuit of the world record at 480 fsw, there is no dispute to her rightful place in history. Sadly, she was lost on December 11, 1971 pursuing that record with her boyfriend, Archie Forfar. Her "unofficial record" may stand as a woman's mark forever.

Dr. Ann Kristovich broke Eckhoff's cave record of 1989 and established the women's mixed gas depth record of 554 ffw on September 2, 1993 in a Mexican cave. Kristovich is part of the Zacaton project exploring one of the world's deepest cave systems. Her dive required over four hours of decompression beginning at 270 feet.

As we approach the twenty-first century, where will the historical reference be? If the past is a benchmark indicator, it will be deeper, longer and totally unexplored...

NOTE

Excerpted from "Deep Diving: An Advanced Guide to Physiology, Procedures & Systems" by Bret Gilliam (with Robert Van Maier and John Crea), 2nd Edition 1995.

Available directly from author Bret Gilliam. Each copy signed and numbered; only 40 left in total. Each copy will be personalized to the buyer as well. 398 pages, lavishly illustrated with diagrams, tables, graphs, and photography.

50 USD each. Send check to:
Bret Gilliam
54 Stonetree Rd.
Arrowsic, ME 04530

Phone: +1-207-442-0998
Email: bretgilliam@gmail.com