Tech Diving Mag

Research - Development - Exploration

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Issue 29 – December 2017

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Editorial

Welcome to the 29th issue of ***Tech Diving Mag***. It's our anniversary, and we're celebrating it by releasing a free, Lite version of Ultimate Planner. Get it at www.techdivingmag.com/ultimateplanner.html.

A quick reminder: as an endeavor to share knowledge and experience, ***Tech Diving Mag*** finds it inevitable to bring up controversial issues. Information published by ***Tech Diving Mag*** are always obtained from sources believed to be reliable. However, ***Tech Diving Mag*** can not guarantee neither the accuracy nor the completeness of any information published in its issues.

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Asser Salama
Editor, Tech Diving Mag

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Acclimatization

By Asser Salama

A long time ago I was taught that multiday diving is a significant risk factor for DCS. Some dive computers available today penalize the diver by dialing down the M-values through a reduced gradient. For example, the Suunto RGBM will calculate some 90 percent reduction for multiday diving in a seven-hour surface interval.[1]

Acclimatization is when a diver is at reduced risk of DCS as a result of conducting dives during the preceding days. In 1967 a study demonstrated the effect of acclimatization in an analysis of 40,000 air decompressions of caisson workers. The incidence of DCS dropped from approximately 12 percent to 1 percent over the first 10 to 15 decompressions (five days per week). Acclimatization was lost during two to 10 days off.[2]

Through the one-year period March 4, 1989, to March 4, 1990, Gilliam compiled data for a total of 77,680 dives, including customers and professional staff aboard his 140-meter (457-foot) diving cruise ship Ocean Quest. He noticed that some validity to the hypothesis of what he called then “adaptation” must be given serious consideration. His team of dive professionals worked aggressively for four straight days and then received three days off before resuming the same schedule. Most made between 500 and 725 dives in the one-year period. Many routinely performed dives in the 75-meter (250-foot) range or greater, on air, with subsequent repetitive dives, and yet no DCS hits were recorded in any staff.[3] Gilliam suggested that the “multiday skip” protocol should be validated later.

Some interesting data on acclimatization was presented at DAN’s Technical Diving Conference in January 2008. The general viewpoint that was endorsed is that multiday diving is not a significant risk factor for DCS.[4] In 2013 a study showed that four consecutive days of identical daily diving can actually reduce bubble formation, representing what is likely a positive acclimatization to diving.[5] This study pointed out that although bubbles do not equate to DCS, it is reasonable to accept that the presence of fewer bubbles is desirable. So in conclusion, the mechanism of acclimatization to decompression stress is still unknown.

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Excerpted from *Deep Into Deco: The Diver's Decompression Textbook*. The title is available at:

https://www.bestpub.com/books/scientific-diving/product/428-deep-into-deco-the-diver-s-decompression-textbook/category_pathway-42.html (print, electronic and combo versions)

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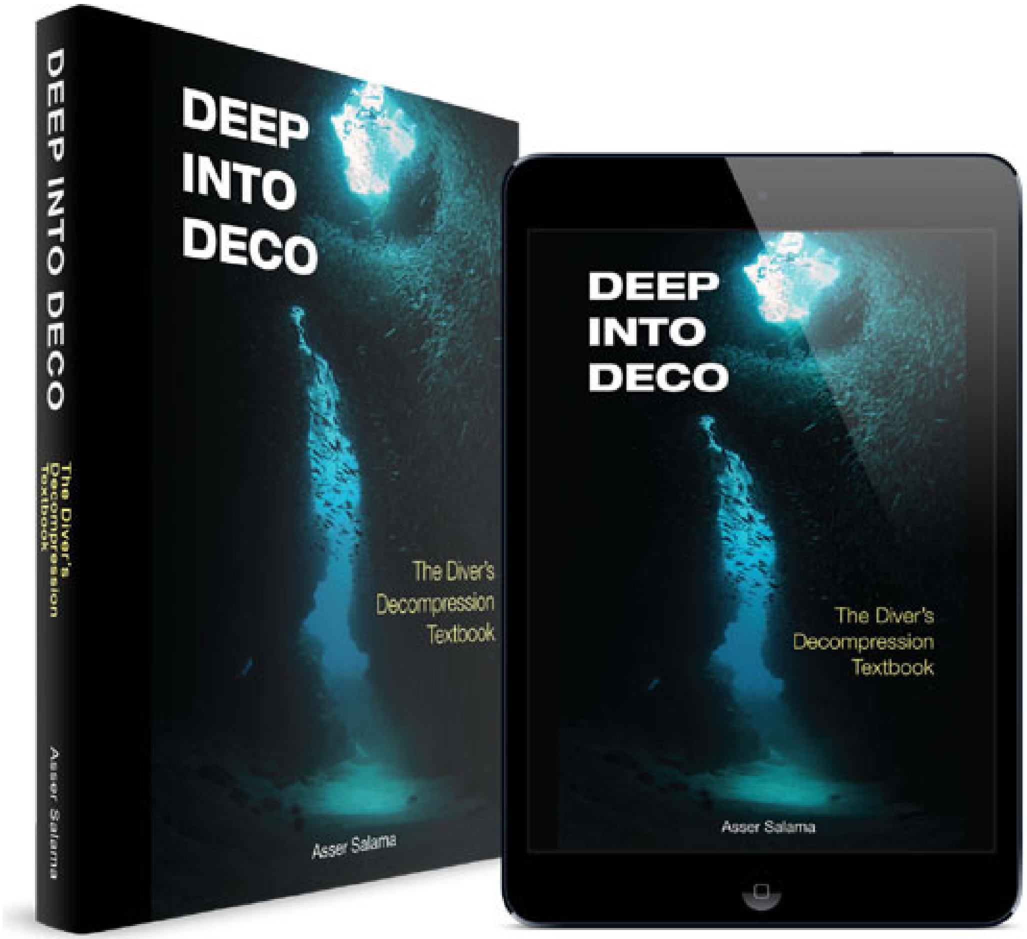


Dealing with Denial
Getting Bends Out of the Closet

By Bret Gilliam

Implausible though it may seem, DCS denial lives on in our ranks, even in the face of serious injury or death. So what does it take to change a bad attitude?

Decompression sickness (DCS) or 'bends' is a statistical inevitability in diving. It has no conscience and rarely abides by set rules. Although we can identify certain predisposing factors in the general dive population, it remains a challenge to explain the exact mechanisms of physiology that allow one diver to become bent while his partner escapes unscathed. It is best that divers, particularly those in the technical community, accept that DCS hits will occur – eventually – and take steps to deal with treatment responsibly.

Of concern to many of us in the business of treating divers is the prevalence in our sport of an unfortunate mindset that consistently denies the possibility of DCS. Indeed, a certain stigma has become attached to reporting symptoms. It's a trend that flies squarely in the face of common sense and logic. Why would any thinking person ignore symptoms knowing that DCS manifestations are progressive in nature... they get worse with time. Further, delays in reporting symptoms and seeking treatment only contribute to a poorer prognosis for recovery.

Historically, a denial of symptoms with its attendant delay in treatment has proven to be the rule rather than the exception in sport diving DCS injuries. Hopefully, the enlightened diver of the 21st century will be pivotal in reversing this 'head in the sand' mentality. We have to remove the stigma of 'blame' so improperly associated with DCS reporting. Typically, a bends hit is not someone's fault. A diver can play everything in his dive plan precisely by the book and still get hit. Likewise, a deliberately high-risk dive profile may not produce symptoms. The point here is that diving leaders must stop pointing fingers and using antiquated analogies ("he screwed up and he got bent, the idiot!"), or this continued reluctance to report symptoms will prevail.

Almost all of us know individuals who have surfaced after a dive and variously exhibited DCS symptoms but steadfastly refused further evaluation or even basic first aid such as surface oxygen by demand valve/mask. There's nothing macho in an attempt to 'tough-out' shoulder pain or progressive numbness: that's just plain stupid.

In the working and commercial diver ranks an entirely different attitude prevails. Divers are trained to report symptoms as soon as possible and the attitude of diving supervisors is one of accident 'containment', not of the accident 'crisis' evident in many sport diving situations. Bends is regarded as an occupational hazard that will occasionally take place and commercial operators and the more progressive sport diving facilities regard DCS as a manageable scenario. For the best outcome, divers and chamber supervisors work in a partnership of honest reporting of even slight symptoms with prompt evaluation and treatment.

With few operational recompression chambers at remote resort sites until the late 1990s, divers in need of DCS treatment were faced with expensive medivac transportation and significant delays, even in the best of circumstances. Possibly as a result of this, many so-called 'experts' were prone to overly broad condemnations of sport divers who got bent; this attitude only contributed to diver denial. Negative peer pressure and professional loss of face effectively influenced divers to ignore DCS symptoms and to hope – mistakenly – that they would somehow get better without treatment. Rarely did this happen.

Most chamber supervisors that I have known in my career feel that if DCS is promptly reported and evaluated with ensuing on-site treatment, then the prognosis for complete resolution is excellent. The view of many commercial diver medics and chamber operators can be summed up this way: "No matter what the problem, if reported and treated quickly, we can clean the diver up". Type I DCS (mild symptoms, pain only) affords less risk than Type II DCS (serious symptoms, central nervous system involvement), but in either presentation aggressive oxygen therapy and prompt recompression has produced close to a 98 percent success record. Many academicians find fault with the commercial operators' confidence in resolution of symptoms but their track record is enviable.

Changes in attitudes

In March of 1991, I was an invited speaker at the joint DAN/AAUS/NOAA Multi-day Repetitive Diving Workshop held at Duke University. For the first time, this conference included representatives from the sport, commercial, scientific, and technical diving communities, assembled to compare notes on actual DCS incidence rates in the field. Some interesting statistical patterns emerged. The overall incidence of DCS for commercial divers was (approximately) one in 1,000 dives, for sport divers it was one in 10,000 dives and the scientific diving community rated an extreme low of one in 100,000 dives. (Sampling from the then-emerging technical segment was so low it was inconsequential and not worth tallying.)

With this rather startling multiplier of 10 between groups, it would be tempting to draw the too obvious conclusion that the scientific diving group is 100 times safer than the commercial diving group. Actually, the incidence rates are interesting for discussion purposes but do not reflect much data to produce true comparisons of relative dive safety vis-à-vis DCS risk. Rather, a clearer pattern of diving 'attitude' was defined. Discussion of acceptable rates of DCS provided the best indication of how varied schools of thought can approach a complex problem from entirely different angles.

Most scientific diving projects are planned from inception to eliminate as much risk as possible from all phases of the diving operation. This is accomplished through strict training and supervision of divers, and a markedly conservative discipline in dive profiling. In short, every possible precaution is taken to reduce the possibility of a DCS occurrence. At the other end of the spectrum, the commercial diving community must deal with a job performance/task completion goal motivated by economics. Therefore, the concept of 'acceptable risk' comes into play for both groups... each dealing with risk differently.

By extremes of discipline, supervision, and training the scientific community hopes to prevent DCS incidence. With the use of highly trained supervisors, diver medical technicians and on-site recompression facilities, the commercial companies aim to effectively manage any accidents that may occur. It is difficult to quantifiably gauge the 'end user' effectiveness of either group since DCS still occurs in scientific and commercial divers; the distinction being that if a commercial diver gets hit he benefits by immediate and state-of-the-art medical treatment that may not be available to a science diver in a remote locale. Per capita DCS rates may or may not reflect the effectiveness of either approach to accident management, but the commercial operators are steadfast in their opinion that immediate evaluation and/or on site treatment are an acceptable alternative to a lesser statistical incidence rate.

Deserved, undeserved

We'd all agree that no bends hit is good. One commercial diving medical professional made this point at the conference: "While most sport and scientific dive operations would like to reach a goal of zero per cent DCS incidence, in commercial diving this is simply unrealistic. Ideally, we would like to reach a zero rate on Type II hits, but we still feel that our protocols allow us to treat DCS effectively enough that Type I hits are essentially manageable."

A good analogy, he said, is that we accept a worker using a hammer will eventually hit his thumb and when he does we'll treat it. If we put a diver in the water to work, eventually he will get bent and we'll treat that as well. That's the reality. The conference delegate added, "We have the technology to handle such hits and we feel that this is a more responsible approach than the elusive belief that we can eliminate DCS. It's going to happen; we all know that. Let's be prepared to treat it." Importantly, he noted, "our divers feel that our system works and it's their butts on the firing line."

Further distinctions are sometimes made between 'deserved' and 'undeserved' DCS hits. Simply, hits from dive profiles that carry a higher risk of DCS exposure are deemed 'deserved'. These might include table or dive computer limits violations, deep repetitive or extreme reverse profile dives. Hits following dives within accepted limits are considered 'undeserved'. This is not to say that as chamber supervisors we sit back and blithely pass judgment on patients. Categorizing DCS hits in this manner merely allows a perspective on reasons for the presentation.

Aggressive O2

First and foremost, we have to encourage reporting of symptoms at the earliest observation. Second, the importance of surface oxygen by demand valve/mask cannot be overemphasized. Dr. Jefferson Davis was one of the earliest advocates of aggressive 100 percent O2 delivery in the field and his pioneering work has resulted in the now accepted practice of oxygen therapy as a first line of treatment en route to the chamber. A significant percentage of symptomatic DCS patients will relieve following a 30-45 minute oxygen-breathing period if delivered by demand valve/mask. During a year long period as President of Diving Operations for Ocean Quest International, I observed nearly a dozen cases of symptomatic DCS clear completely following delivery of demand system O2 during patient transit to our chamber on the ship. Free-flow systems are far less effective and are wasteful of the gas.

I ran the Ocean Quest diving program along similar guidelines to a large commercial operation: expect the worst and be prepared to deal with it. We were very successful in encouraging divers to report any symptoms and had a 100 percent resolution rate on every one of the DCS cases we treated. Our overall incidence rate came out to be approximately one case in 12,000 dives; this is significant since our diving program was unlimited with respect to depth and repetitive dives allowed each day. In the space of one year we conducted almost 80,000 dives! Ocean Quest remains the largest diving operation in history. We averaged as many as 1,200-1,400 dives per day sometimes as a matter of routine.

Thankfully, we are seeing more and more fully operable field chambers coming into use. Grand Cayman, Cozumel, Roatan, Palau, Ambergris Cay, the Galapagos, the Red Sea's Sinai, and even some live-aboard expedition vessels all feature state-of-the-art treatment facilities that would have been unthinkable only a decade ago. But remember, the chamber is an effective tool only if used – hopefully as soon as the individual suspects a problem. It's incumbent on all divers to take personal responsibility to report any abnormality that could be even remotely linked to DCS. Using 100 percent O2 at once and seeking professional evaluation and a test of pressure is key if the possibility of DCS is suspected.

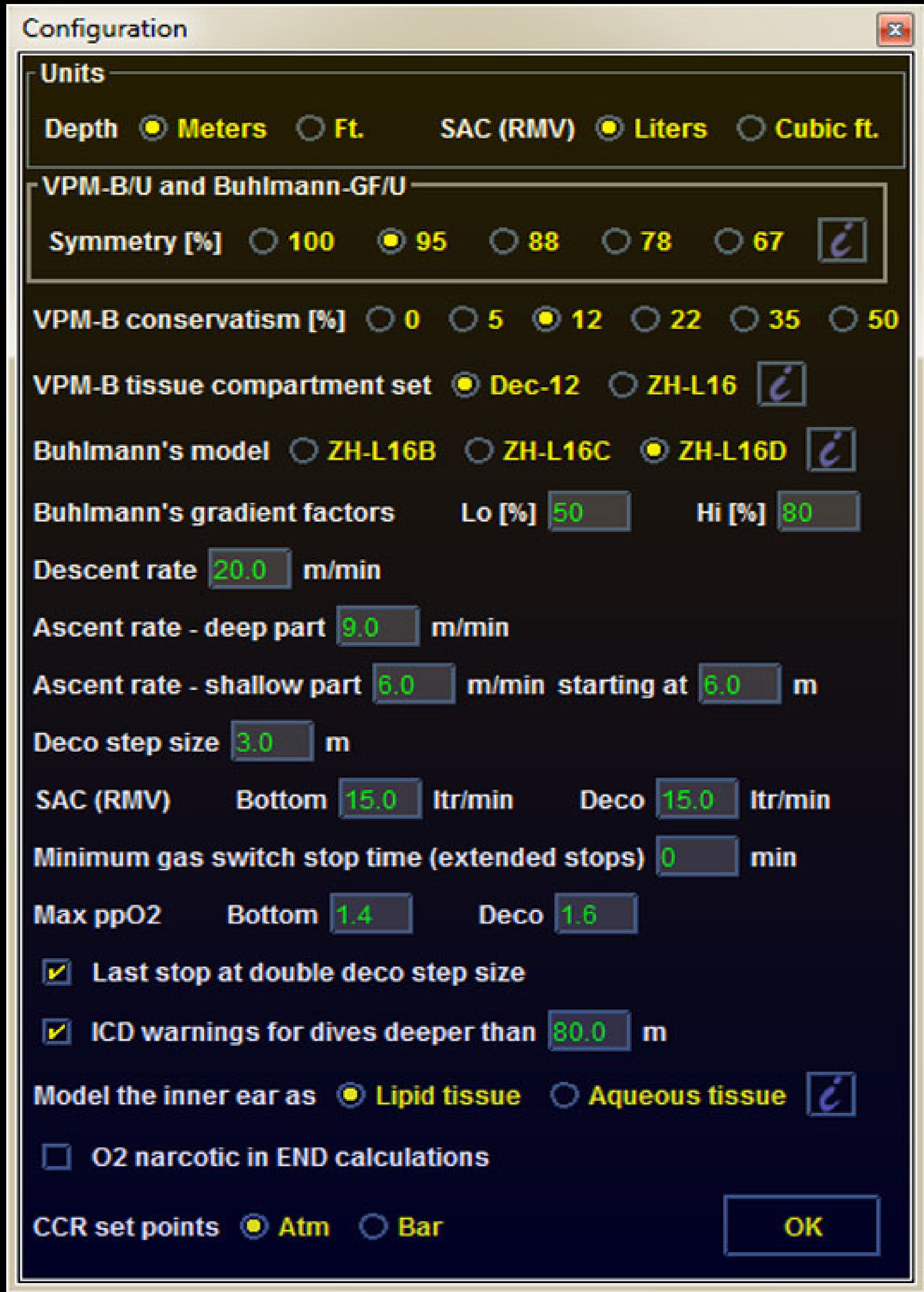
Get bent in a remote area like this and you will have to deal with the treatment yourself. For remote expedition projects, more attention to details is required.

DCS contingency

All divers should have a complete and detailed contingency plan for DCS management. For higher risk dive profiles and remote expedition projects, more attention to detail will be required and should include the provision for on-site recompression either in a properly staffed and set-up field chamber or through use of an evacuation chamber. In-water recompression protocols also present options that are viable for experienced personnel who understand the protocols.

The advent of affordable medical insurance through an organization such as DAN, removes the financial deterrent to seek help if/when DCS is suspected. There is nothing macho or cool about denial of DSC symptoms that could very well result in lasting injury such as paralysis or worse. It's time divers woke up to the fact that bends is an injury for which common sense demands treatment. Finally, encouraging prompt reporting without any peer or professional blame, will vastly improve the safety of a sport infamous for symptom denial.

Bret Gilliam is a 45-year veteran of the professional diving industry and operated recompression chambers for over 20 years. He is credentialed as a Recompression Chamber Supervisor, Diver Medical Technician, and developed the most widely used remote in-water treatment protocols currently in use when evacuation is not an option. He is widely published on the subject of diver treatments, physiology, and emergency procedures.



Britannic 2017 Italian Expedition

By Flavio Fanelli

1) Starting in 2016, my friend and CCR instructor Aldo Ferrucci organized the *Britannic* first Italian diving team and gave me the opportunity to be part of the group. His plan was to dive the His Majesty's Hospital Ship (HMHS) *Britannic* a year later, in September 2017.

I've been diving since 1974, a year before the wreck was discovered by Jacques Cousteau, and I've been probably dreaming on diving her ever since. Of course over the almost last 40 years it was only a dream, like for an average climber dreaming on the Everest. But keep dreaming and voilà, here we are in Kea, Greece setting the gear up for diving the famous *Titanic* sister.

2) A year window to get there is probably the longest waiting time for any in the world given dive. Waiting time involves mainly the necessary permits to dive the wreck. Permits from the wreck owner Simon Mills and the Greek government, which rules over any historic wreck (more than 50 years old) on Greek waters. And usually the permits are restricted to a maximum number of divers and in a specific date.

3) The Cyclades are well known for been a windy and wavy geographic region, and the forecast is usually quite variable even with a couple of days warning, meaning that setting up a tour over there with an almost a year anticipation could turn into no diving at all, and fees are not refundable! So diving the wreck is more or less a bet, even in the best season to do that which is October and November usually. Even with the right forecast, currents could be quite strong, and even diving with a DPV is at least challenging, and getting lost is not an option in a heavy traffic channel.

4) After a year, and with everything ready the 12 member group started the trip to Kea with different means, some by car and ferry, some by plane and some all the way down by car through the Balcans. My buddy Cedric and myself opted for this last one, along with some other members. At the end anyway all members were there on time.

5) Regarding the equipment, basically we had to have everything on board, Sofnolime, 4 Bailouts each, etc… so we chose to get there with a van with room enough for the rebreathers and the rest of the needed gear.

6) Kea island is a small touristic summer location on the other side of the channel with hotels, restaurants and spas. After-summer season is quite nice and not overcrowded, so staying there at the Porto Kea Suites was a plus: a nice hotel, nice rooms and a swimming pool. Not a bad choice at all.

7) The dive center of our choice was Kea Divers. His owner and manager is Tazvelakos Yannis, a wonderful guy doing his best to keep up with heavy tasks, not forgetting to mention Georges Vandoros, the divemaster and safety officer who was professional, cheerful and indispensable for this kind of operation and always doing any given task with the highest performance. The dive center provided all we needed to do our mission in the best possible way.

8) Our first dive was on the *Burdigala*, a nice wreck very close to the port of Kea, with an average depth of 65 meters. Sweeped by strong currents, this was the perfect spot to test our gear before tougher dives on the *Britannic*.

9) Diving rules of engagement, basically penetrating the wreck is forbidden. Of course taking souvenirs (other than pictures) is a no-no.

10) *Britannic* day one, well this was a tough one. My buddy Cedric and I were the first down the shot line, with the mission of setting up a strobe light and a reel from the shot line to the gunwale, which proved to be a tough job, since the shot line was sent down the day before, and dragged away some 60 meters from the wreck because of a strong current in an unusual direction. We were there at 110 meters, scootering at maximum power and moving like snails, trying to figure out where the wreck was, until we saw a huge, really huge, shadow of the wreck. We were on the hull side. After securing the lines our deco was over 210 minutes so after a quick peek over the poop deck, we went the way back allowing the rest of the guys to safely dive the wreck.

11) *Britannic* day two, well this time we had the same job of the day before, but it was done quicker since there was no current. Another shot line was sent down the day before on the deck side, in order to choose the best one to descend on. We choose the same one we used before, because it was already secured and we were lucky enough that the lack of current brought the shot line a few meters from the gunwale. And this was the best dive of my entire life! The shot line put us more or less on the halfway between mid-ship and the transom, so we started scootering our way to check on the huge wreck propellers, then back into the promenade deck, trying to catch every possible thing, life boats davits, cranes, bollards, portholes, you name it the wreck has it all. Even the Cousteau plate that is on the port side over the gunwale. This time we were already over a 240 minute runtime so after a final glimpse over this queen we went to the shot line to start our long way back.

12) The day after our more than successful dive, wind and sea started to build up, reaching and average of 35 knot speed. So unfortunately we did not have more chances to dive her again, since our permits were for a week, and bad weather kept it up for more than that.


IN HONOUR OF JACQUES
JACQUES-YVES COUSTEAU
PIONEER / TECHNICAL DIVER.
ONE OF THE MANY FRONTIERS HE TOUCHED.
HIS EXAMPLE HAS ENTICED MANY OF US TO FOLL
HIM AND EXPERIENCE
"THE SILENT WORLD"

13) The wreck is more than what the word **huge** means, and has been dived by less than a hundred person at most. As probably any technical diver knows, it lays on starboard side on a 120 meter bottom since November 1916, when she sank after hitting a German mine, laid some weeks earlier by a U-boat. Although being there for more than a hundred years, she is in very good shape, covered of course by nature. Some planks have rotten over time. Above all she is a grave and a reminder of war cruelty.

14) We learned that scooters, reels and strobe lights are a must for this wreck, that Cyclades weather is unpredictable and that the dives are not easy at all. But she it is the Everest of wrecks, and eventually a wreck that has been dived by less than a hundred person so is totally worth any sacrifice, beside being the *Titanic*'s sister gives her a royal status for any technical diver in the world.

15) And yes we are planning to go back there next year ☺

16) Divers of the group in alphabetical order are Paolo Bagordo, Enrico Bortolotti, Denise Brusoni, Marcello Bussotti, Massimo Canali, Flavio Fanelli, Aldo Ferrucci, Renaud Jourdan, Andrea Mescalchin, Christian Rivolta, Cedric Sarazin and Roberto Strgar, with Caroline Dumas as a backup diver.

During our week in Kea we were accompanied by the French TV, which documented parts of our expedition. It was the main spot of its show, Thalassa, about wreck hunters. It was aired November 13 on FR3.

20 Years Progression

Text by Bruce Konefe

Photos by David Street, Michael Pettersson and Mikko Paasi

Rebreather diving has come a long way in the past 20 years. Back in the days most divers were diving with SCR (Semi Closed Rebreather) or CCR (Closed Circuit Rebreather) without the use of pO2 (Partial Pressure of Oxygen) meters to monitor their oxygen levels. This is mainly speaking of the SCR units. We all know the importance of knowing what levels of oxygen we are breathing. Before pO2 monitors were being used divers would calculate their fO2 (Fraction of Oxygen), flow rate and work load to determine what their fO2/ pO2 would be at certain depths. If any small particles were to get into the system it could very easily plug the orifice and you would not be getting the oxygen you should. Without the pO2 monitors there is no way you would have known what you would be breathing (probably a hypoxic mixture).

When SCR/CCR training courses were first being taught to the open public the instructors were instructed to dive with an open circuit configuration. Diving in open circuit was considered to be less task loading and safer for the instructor. Since the beginning of SCR/CCR diving it has been a common practice that the diver would carry a RBS (Redundant Breathing System) in case of a rebreather failure. Carrying a RBS would allow the diver to switch from the rebreather they are diving with onto the RBS. Once the diver had switched over to the RBS the diver would then abort the dive.

With the lack of knowledge and experience with rebreathers and rebreather training the industry has come a long way. The industry has been able to formulate standards and procedures that have made rebreather diving much safer for the diver and the instructor. When looking back sometimes I find it is amazing how we have survived through these days.

20 years later, where are we at with rebreathers today?

Rebreathers have definitely come a long way from once being called a box of death. The manufacturers have taken the rebreather designs to a new level. Many of the rebreathers that you will see out at the dive site today have pO2 monitors that can monitor not just 1, but 2, 3 and even 4 oxygen cells. These meters will allow you to know what oxygen levels you are breathing at all times. Most of the newer units have redundant pO2 meters in case the primary meter would happen to fail. To take things one step further, there are visual and audible alarm systems to let you know if your oxygen level is too low or too high. Other than just the pO2 meters, the quality of oxygen sensors are improving so that they are becoming more and more reliable and safer. The manufacturers have even designed what is known as a “Cell Checker” that allows you to test the cells before you use them.

Training agencies have changed their stance that now it is “highly recommended” that the instructor dive with the same SCR/ CCR that the student is diving with. The rebreathers have become less task loading where they believe the instructor can safety dive the units with the students. With the instructor on the same unit, this allows the student to be able to see proper demonstrations on how the skills are to be executed.

SCR/CCR divers still and will always rely on a RBS for bailout. However slowly but surely you will see divers carrying a bailout rebreather. For the more experienced CCR explorers it does come to a point where they need too many open circuit bailout tanks. On deep cave expeditions in the past I can remember there were about 15 open circuit bailout tanks staged from 120m all the way to the habitat staged at 6m. With the use of a side mounted or back mounted CCR that would eliminate many of those once needed bailout tanks.

The way of the future

The future is taking us to "twin" back mounted rebreathers and back mounted CCR using a side mounted CCR (for bailout). The side mounted CCR is becoming very popular amongst the technical cave divers.

Twin back mounted CCRs

With the use of a back mounted bailout rebreather this allows you to reduce the amount of off board bailout tanks that you will have to carry. With the primary and bailout rebreather on the back this will also allow for a much cleaner front area.

Back mounted CCR with a bailout sidemount CCR

A back mounted rebreather with a side mounted bailout CCR does not leave the front area open like if you were using a twin back mounted set up. What this does allow is easy access to your bailout CCR where you can remove and replace the unit if needed. In this article's cover picture the diver is diving with a back mounted CCR and a bailout rebreather front mounted (similar to the way that your off board tanks would be mounted). The side mounted unit is an "early days" Proteus P1 with 2 x 1 liter cylinders on-board (1 x 1 liter of oxygen and 1 x 1 liter of diluent, or both cylinders which can filled with oxygen and an off-board supply of diluent).

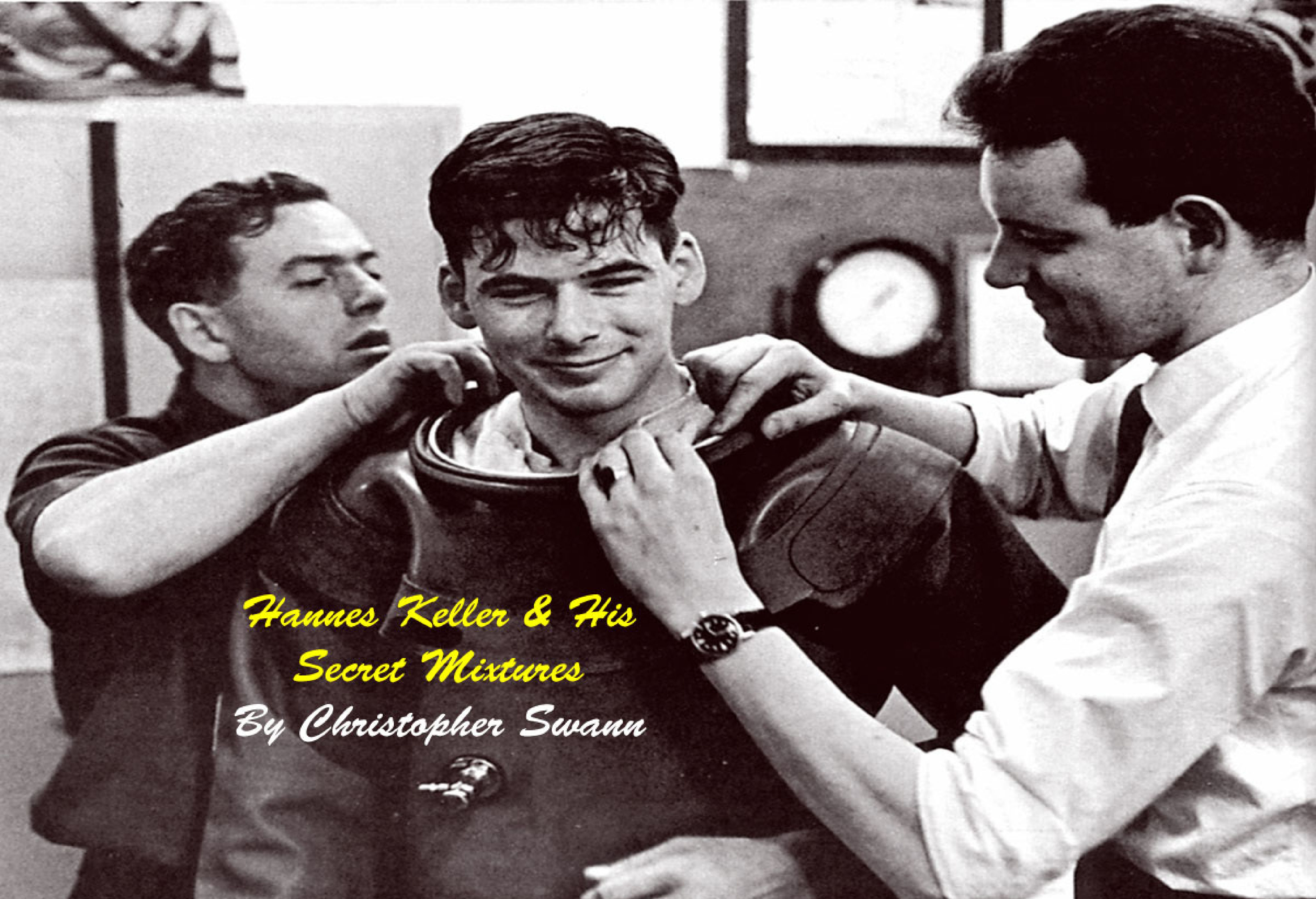
Sidemount CCR

Right now most advancement in rebreather technology is based around the side mounted CCR. Some of these units are even offered with ECCR or MCCR capabilities; with technology like this offering a big step to the technical CCR explorers who travel around the world. Depending on the manufacturer, the sidemount CCR is being offered with onboard or offboard oxygen and diluent tank configurations. If the unit you are diving has off board tanks you can basically use just about any size of tanks you would like. One of the big advantages of the sidemount CCR is that it can be removed and replaced very easily, just about as easy as you with sidemount tanks. Many of the sidemount CCRs can be converted back and forth with very little modifications to the unit. With the wide range of diving offered today this would save on having to buy multiple units.

Where do you think we will be with rebreathers in the next 20 years?

Special thanks to David Street of Dive Systems UK (designer and builder of the Proteus CCR), Michael Pettersson owner of Kasai Village and Mikko Paasi for their photos and contribution.

Bruce Konefe is a pioneer technical cave and deep wreck, sidemount and rebreather instructor training director – with over 20 years full-time experience planning and organizing the most ambitious technical diving expeditions throughout Thailand, Malaysia, Vietnam and the Philippines. Get to know more about him at www.deeptecdiver.com or contact him directly at sidemountdiver@hotmail.com.



Hannes Keller & His Secret Mixtures

By Christopher Swann

An excerpt from *The History of Oilfield Diving: An Industrial Adventure*. Cover image: Keller being suited up at the US Navy Experimental Diving Unit (*US Navy*).

On December 3 1962 the Swiss mathematician Hannes Keller reached the astonishing depth of 1,000 feet in the open ocean off Catalina Island. Keller was outside his diving bell *Atlantis* for no more than two minutes and his companion died during the ascent, but the fact remained that an inspired amateur from a land-locked country had demonstrated that the limits to human exploration and exploitation of the sea lay much deeper than all but a few specialists suspected. And that was not all. Had things gone according to plan, after five minutes at 1,000 feet the divers would have decompressed in only four and a half hours: a schedule they had followed without incident on a chamber dive a month earlier. What was the secret?

Keller had started diving in 1958 in the Swiss lakes, making his own regulator out of wood because he lacked the tools to machine metal. It quickly dawned on him that unlike space exploration, diving was a field where an individual carrying out his own research could have a big impact, and that the way to do that was to break the world depth record. Not wanting to settle for half measures, he set himself a goal of 1,000 feet, four times as deep as any oil company was then drilling. First, however, Keller had to find someone who could help him on the physiology side. That man was Dr Albert Bühlmann, chief of the cardio-pulmonary laboratories in the department of medicine at the University Hospital, Zürich. Bühlmann's field was diseases of the lung. He was also involved with aviation medicine—but about diving he knew nothing whatever.

With Keller's knowledge of mathematics and limited experience of diving, and Bühlmann's knowledge of physiology, they started work. Clearly, to get anywhere near as deep as 1,000 feet it was going to be necessary to breathe a helium-oxygen mixture (in an April 1975 interview in *Skin Diver* Keller said he originally wanted to use hydrogen because he was looking for a cheap method; Bühlmann refuted this).

But they saw difficulties. The US Navy, in its original work, had found that for short duration dives to medium depths a longer decompression was needed for helium than for air. From this, it was concluded that the saturation of the body, and of some tissues in particular, occurred faster with helium than with nitrogen: a hypothesis that Keller and Bühlmann confirmed in the laboratory, establishing the saturation rate for all tissues as 2.65 times faster with helium than with nitrogen. Therefore if helium-oxygen alone were used, the decompression required for a very deep, very short dive would be out of all proportion to the time spent on the bottom.

The procedure devised by Keller and Bühlmann was to compress rapidly with a series of mixtures containing high concentrations of oxygen and a maximum of nitrogen, switching to straight helium-oxygen only towards the bottom, then reintroduce nitrogen as deep as possible in the decompression, with subsequent complete substitution of nitrogen for helium, to accelerate the elimination of helium from the tissues. Decompression was a continuous ascent rather than being done in stages. This combination of switching inert gases and breathing high partial pressures of oxygen throughout the dive (always greater than 2.0 atmospheres) to shorten decompression was naturally kept under wraps and remained the object of intense speculation for several years. The same went for the new method Keller and Bühlmann developed for calculating decompression, with which they formulated some 400 tables for depths to 1,312 feet with the help of a computer at the IBM Centre in Zürich.

In November 1959, Keller descended to 400 feet in the Lake of Zürich in an upturned 50-gallon oil drum weighted down with large stones. Most of the equipment, such as it was, was borrowed, and his emergency ascent device was an old car tyre. It was, Keller admitted, a terrifying experience. The following year he progressed to less hair-raising methods when the French navy, with some prodding from Cousteau, put the chambers of the Groupe d'Etudes et Recherches Sous-Marines (GERS) in Toulon at his disposal.

The first dive, to 820 feet, went off in November 1960, and a further two dives, to 1,000 feet and 700 feet, followed in April 1961. During the compression phase of the 1,000-foot dive Keller went from 300 feet to bottom pressure in two minutes (a compression rate of 350 feet per minute!), which he reported produced dizziness and tremors.

At the time little was made of this. In fact, Keller was exhibiting mild symptoms of HPNS. What Keller and Bühlmann did not know (and neither did anyone else at the time) was that nitrogen, which they were using purely to shorten decompression, also, fortuitously, counteracted HPNS—and Keller was compressing with a maximum of nitrogen most of the way, which conferred maximum protection. It may well be that Keller was minimally susceptible to HPNS anyway, but it is certain that had he tried to duplicate the 1,000-foot GERS dive on helium-oxygen alone he would assuredly have exhibited severe symptoms, including possibly vomiting, with the consequence that the physiological difficulties of rapid descent to great depths would have been confronted many years earlier than they in fact were.

By the time Keller completed the dives at GERS, the news that a wonder boy out of nowhere was diving to great depths with God-knows-what exotic gas mixtures—and returning to the surface with seemingly ridiculously short decompressions—was reverberating throughout the professional diving community. As Dr Val Hempleman, then Superintendent of the Royal Naval Physiological Laboratory (RNPL) at Alverstoke, put it:

'He was making all us conventional diving groups—USN, RN and French navy—look like a group of yesterday's men with no real grasp of the correct diving physiology necessary for safe, but rapid, decompression. The interested scientists and diving physicians began to take sides in the debate about how Keller was succeeding to apparently make fools of us all.'

Nowhere was the debate more bitter than in the USA. Captain George Bond, later credited as the father of saturation diving, was convinced that Keller had hit upon a successful technique that should be acquired by the US Navy. Captain Robert Workman was equally convinced there was nothing to be gained. In the end, it was agreed that since as far as they knew Keller had only made deep dives with a few seconds at bottom pressure, the navy should offer him a contract to demonstrate a dive to 700 feet with ten minutes at maximum depth.

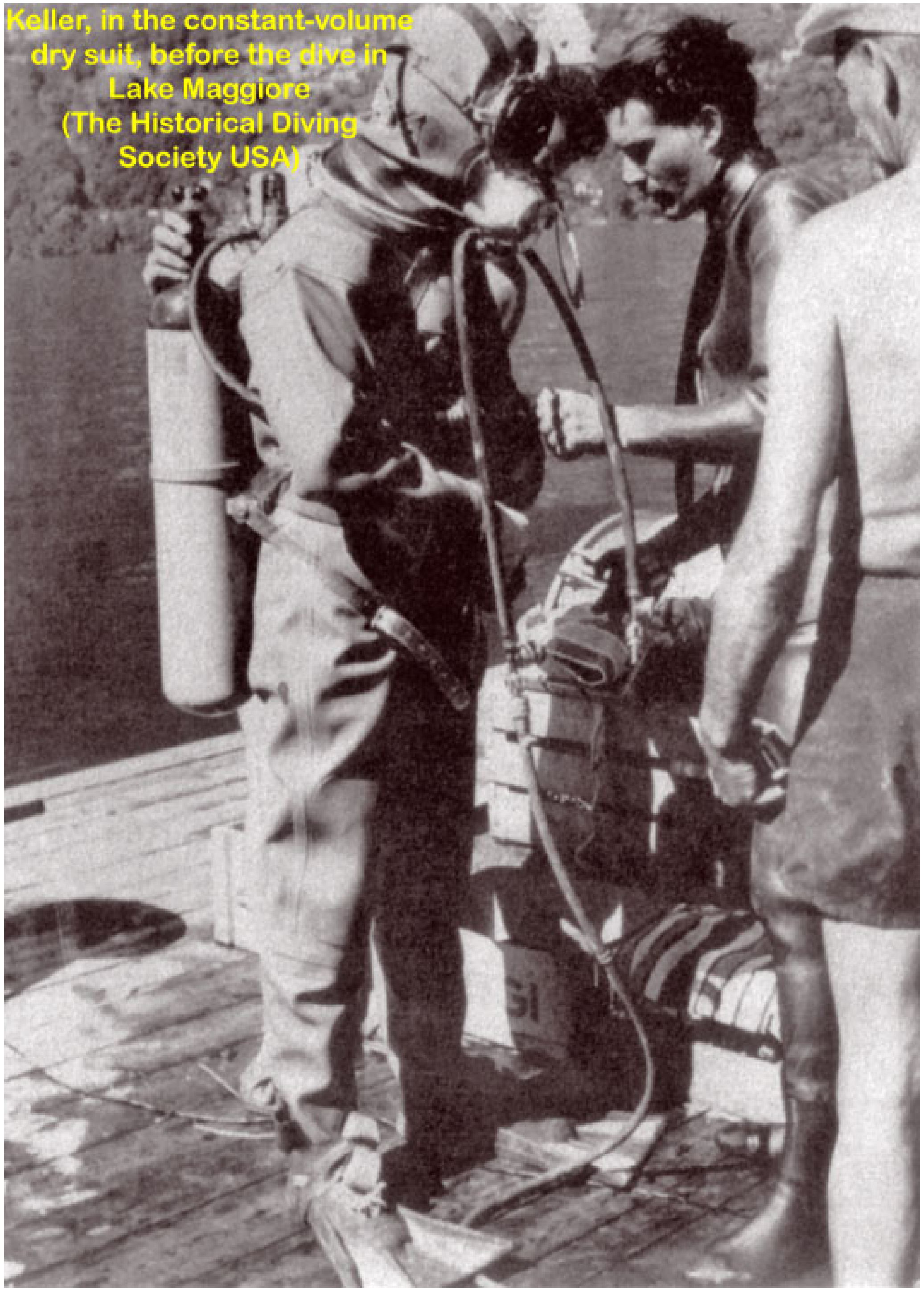
Further controversy ensued when Keller and Bühlmann, who thoroughly distrusted the US Navy, demanded complete control of the chambers at NEDU in Washington, where the dive was to take place. This was unheard of. The US Navy was not accustomed to handing over its facilities to foreigners, still worse to those from a country with no coastline.

Eventually a compromise was worked out and the dive went ahead on May 10 1961, with Keller decompressing in the mind-boggling time of approximately 100 minutes. Hempleman, who was present at the demonstration, was so astonished by Keller's performance that he followed him around for several hours afterwards, expecting to see some adverse reaction; but Keller was totally unaffected. Looking back some 30 years later, Hempleman recalled:

'This was apparently a victory for the Keller approach and it caused a tremendous rise in support for deep diving in the US and Europe. The USN could not be told how to conduct deep diving by Swiss amateurs: pride was at stake and research on decompression received support in all interested countries. It was as if circumstances had conspired to focus attention on deep diving research at a time when the knowledge gained in this burst of activity would be very useful shortly afterwards for the exploitation of offshore resources. All credit to Hannes Keller for disturbing the peace, gaining amazing publicity, and thereby provoking systematic deep diving work!'

Nonetheless, the general reaction at NEDU to Keller's demonstration dive was that he was a physiological freak, and there was considerable doubt whether the procedure would work with anyone else. Keller decided the only way he was going to prove that his method was valid, and persuade the US Navy to give him a research contract, was to take someone else with him on a deep dive.

Having a flair for publicity, Keller went to see Kenneth MacLeish, an editor at *Life*, and proposed that he buy a round-trip ticket to 700 feet. The price: $2,000. *Life* would get a dramatic and unusual story, and Keller would show the navy and everybody else that an ordinary human being could make such a dive and return to surface pressure without incident, just as he had. Understandably, MacLeish wanted to know what he was letting himself in for. How dangerous was it? Very dangerous, replied Keller, adding that he himself was frightened. Such an honest admission satisfied MacLeish that he was not dealing with a lunatic, and he agreed to go.



Keller, in the constant-volume dry suit, before the dive in Lake Maggiore (The Historical Diving Society USA)

The dive took place on June 28 1961 off Locarno, at the Swiss end of Lake Maggiore, in the presence of Lieutenant Commander Charles Aquadro, the official US Navy observer. There was no diving bell. The divers were lowered from a raft, on a platform that Keller and his assistants had built specially for the dive, breathing through mouthpieces from onboard cylinders of premixed gas. Earlier on, convinced—correctly—that everyone was trying to find out the composition of his gas mixtures, Keller had planned on diving with a home-made closed-circuit breathing apparatus. On a visit to Keller's workshop in Winterthür, Hempleman and others from RNPL, seeing he was barely aware of the difficulties involved, persuaded him to go to open-circuit, even though it would be more costly in gas usage and was also liable to donate free gas samples of his secret mixtures.

There were four changes of gas on the way down and four on the way up, starting and ending with pure oxygen and preceded at the surface by one hour of oxygen to flush the nitrogen out of the tissues. Both divers wore Spirotechnique constant-volume dry suits, with two bottles of 'universal mixture' on their backs in case of an emergency ascent. MacLeish received three days of training, and then it was straight to a new world record of 728 feet. Whereas the Royal Navy had taken almost 12 hours to decompress George Wookey from his five-minute stay at 600 feet—which admittedly included treatment for a minor bend—Keller and MacLeish went from the surface to 720 feet and back in one hour.

Having thus shown the sceptics that their approach was indeed applicable to the average man, Keller and Bühlmann got two research contracts with the US Navy for a series of deep dives, using different subjects, to 500 feet, 650 feet, 820 feet and 1,000 feet. The dives took place in 1962 at the University Hospital, Zürich, in a two-place chamber designed by Keller and built by the Swiss firm Sulzer. Those dives led up to the 1,000-foot dive at Catalina Island.

For the dive in the Pacific, there was no question of descending and ascending exposed to the water as in Lake Maggiore. This time Keller drew up a plan for a cylindrical diving bell 7.5 feet high and 4 feet in diameter, which Sulzer then manufactured. Financial support for the venture came from the US Navy, with Shell Oil, as observers, providing the coring vessel *Eureka* as the support ship. According to the *Life* article that appeared after the event, MacLeish had intended accompanying Keller again. For whatever reason, that did not happen; and the second diver was the English journalist Peter Small, a co-founder of the British Sub-Aqua Club who had recently left Fleet Street to take on the club's new magazine *Triton*.

On October 30 1962 in the last dive of the US Navy series, Keller and Small spent five minutes at 1,000 feet in the University Hospital chamber. Decompression lasted 270 minutes with the divers breathing the following mixtures through mouthpieces:

Bottom	8% oxygen, 92% helium
500 feet	15% oxygen, 60% helium, 25% nitrogen
165 feet	30% oxygen, 70% nitrogen
133 feet	50% oxygen, 50% nitrogen
50 feet	100% oxygen

This was a dry run for the open-ocean attempt and went off without any decompression sickness or other difficulties.

On December 1st, after arriving in California, Keller and Small made a 60-minute dive in the *Atlantis*, swimming out of the bell in turn at 330 feet. Decompression was 126 minutes, again without any symptoms of decompression sickness. *Newsweek* later reported, however, that

Small had had the bends several times before the 1,000-foot dive and that this had led the US Navy to try to persuade Keller to replace him, but without success. Given that there was a good deal of inaccurate information circulating after the dive, the report may have been incorrect.


Peter Small (The Historical Diving Society USA)

As before, the divers wore constant-volume dry suits. Since it has a bearing on subsequent events, it is important to understand that in the constant-volume suit the face mask and mouthpiece are built into the hood, which clamps to the neck of the suit. By exhaling into the suit instead of through the mouthpiece, the diver can adjust his buoyancy, thereby maintaining a constant volume at any depth. Valves at the head and feet prevent over-pressuring. On the surface, the detachable face mask glass is left open, hanging on a retaining chain. Although they were in the dry, Keller and Small kept their faceplates closed throughout the dive—as on the chamber runs, to save money the bell was filled with air not helium—breathing the various gases from cylinders outside the bell by way of a semi-closed system that scrubbed the carbon dioxide.

The dive was started and stopped twice because of bad weather. On the third attempt the bell reached the target depth in 16 minutes as planned, with Keller, in contact with Bühlmann by telephone, pressurising the bell as it descended. Pressurisation could not be done on the bottom because the *Atlantis* had an internal hatch but no external hatch, and therefore relied on pressurisation to keep the water out during descent. Down to 600 feet, the divers breathed a maximum of nitrogen, then switched to helium-oxygen. The bottom mix, as on the chamber dive in Zürich, was 92% helium, 8% oxygen.

On arrival, Keller, breathing from bottles on his back, left the bell. Quite what happened next is unclear. Some sources said Keller was outside for two minutes, and that he tried to plant the Swiss and American flags in the bottom. A navy observer who was watching the picture from one of the two external television cameras was reported in *Newsweek* as saying that he saw someone get on the ladder and drop the flags, and that the excursion lasted no more than 30 seconds.

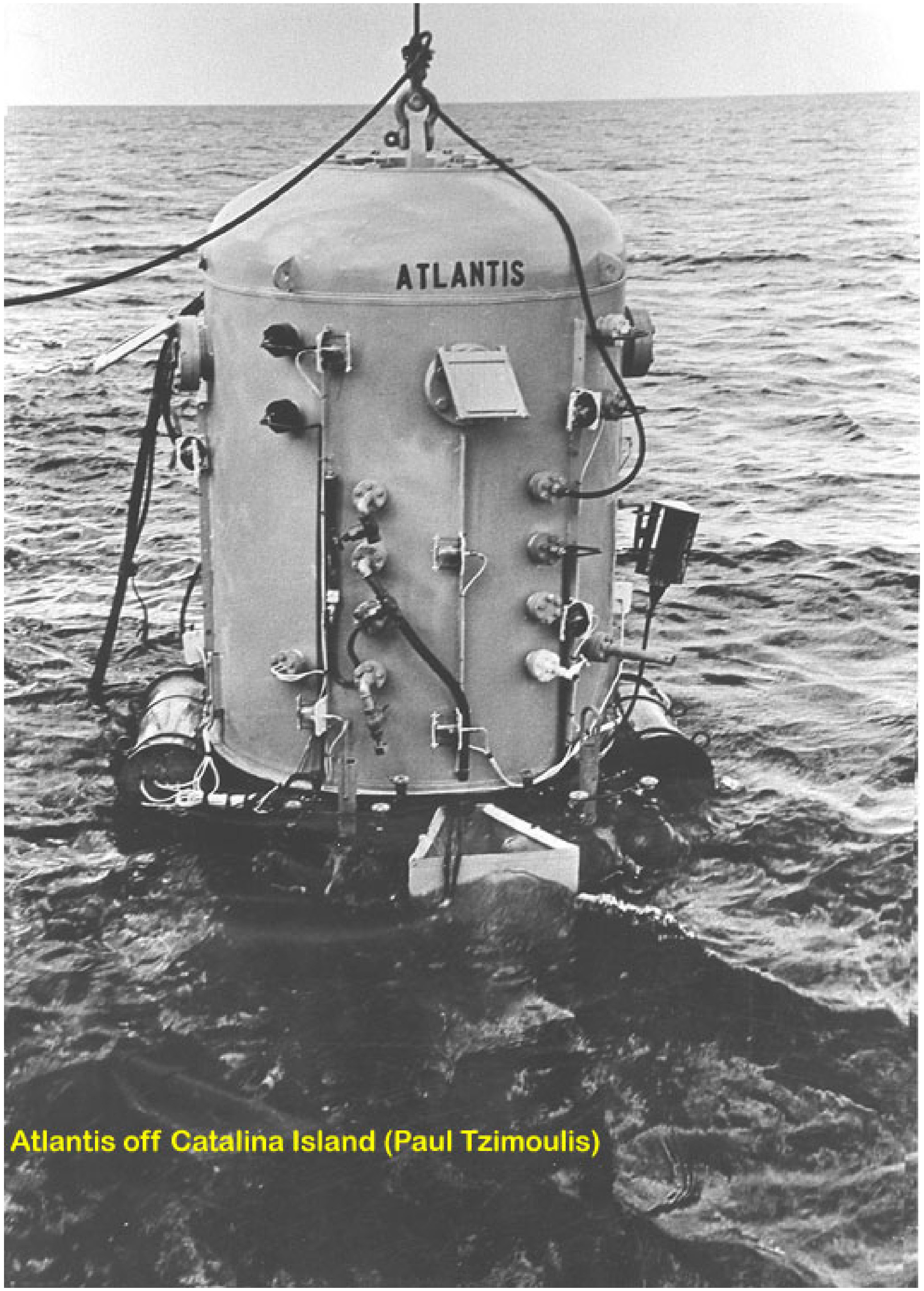
Either way, when Keller returned to the bell and reconnected to the onboard gas supply, he realised that the external cylinder of deep mix was almost empty. Later it was thought that a pressure reduction valve had leaked, although it subsequently proved impossible to reproduce the situation. Knowing he could not continue to breathe from the mouthpiece, Keller opened his faceplate and immediately passed out (breathing air deeper than 600 feet results in loss of consciousness). Small was instructed to do the same, but for some reason did not comply. The bell was then raised to 200 feet in a continuous ascent lasting 17 minutes as scheduled, at which point Keller regained consciousness and opened Small's faceplate. Keller now closed the hatch to seal the bell so that it could be brought on deck; but it quickly became apparent the *Atlantis* was losing pressure.

The two safety divers, Dick Anderson and Christopher Whittaker, a 19-year-old English friend of Small's, twice swam down to the bell to see what was wrong. On the second dive, they discovered the end of a swim fin stuck in the hatch; as soon as Anderson cut it away the leak stopped. Whittaker, who had appeared fatigued after the first dive, failed to surface from the second descent. His body was never found.

By the time the bell was lifted on board, the internal pressure was at 165 feet. Keller was breathing the 50% oxygen, 50% nitrogen mixture called for at that point in the decompression. At 50 feet, he switched to 100% oxygen. Ninety minutes after Keller opened Small's faceplate, Small recovered enough to be able to talk, after which it appeared to Keller that he fell asleep.

In the meantime the *Eureka* set course for the Long Beach Naval Station, on the assumption that after what had happened both divers might need to be recompressed in a facility equipped for prolonged treatment. During the crossing from Catalina, the decompression was extended from the planned 270 minutes to 410 minutes to hold Keller and Small under pressure until the vessel docked.

When the *Eureka* tied up, the bell was lowered to the quay. Keller emerged in good condition, without any indication of bends; Small, who Keller had thought was asleep, was dead: exactly when he had died is not clear.



Atlantis off Catalina Island (Paul Tzimoulis)

Thus a giant leap into the depths ended in tragedy, rendered still more tragic shortly thereafter by the news from England that Small's wife Mary had committed suicide. Not for another ten years, when two divers locked out at 1,010 feet from the USN Mark II Deep Dive System off San Clemente Island, would divers again reach such depths in sea.

After the accident, Keller and Bühlmann continued to maintain a veil of secrecy around their 'magic gases' as far as the press was concerned; but in 1963, as part of their contract with the US Navy, Bühlmann submitted a report to Captain Workman in which he gave complete details of the breathing mixtures and dive profiles. Two years later, for the benefit of their scientific colleagues, Keller and Bühlmann co-authored a paper in the *Journal of Applied Physiology* entitled 'Deep diving and short decompression by breathing mixed gases'. In the circles that counted, the guessing was over.

That was not the end of the story, however. On hearing of the deaths at Catalina Island, the Italian company Micoperi had approached Shell International Petroleum in The Hague. The Italians said that much as they regretted the loss of life, Keller had at least shown that it was possible to go to 1,000 feet and survive, and they urged Shell to fund Keller and Bühlmann to do further research. The persuasion worked.

In 1964, Keller and Bühlmann signed a contract with Shell. A new chamber facility, large enough to allow prolonged experiments, was installed at the University Hospital. Work began with saturation dives to 100 feet to determine the longest half-time values for helium and nitrogen, then progressed in 1965–66 to bounce dives to 720 feet. At the same time, Shell set up a field-testing programme in the Mediterranean with Micoperi, using a large specially designed combination habitat-diving bell, *Capshell*.

In August and September 1966 professional divers from Micoperi and sport divers from Switzerland made a 100-foot saturation dive, followed by three bounce dives and one saturation dive to 720 feet. After the dives, Shell and Micoperi formed a 60/40 joint-venture company, Sub Sea Oil Services.

The Shell research contract ended in February 1981. Between 1965 and 1981, Bühlmann conducted some 40 dives to 650 feet and deeper, the last and deepest to 1,650 feet, with an excursion to 1,900 feet. By then, seeing the Swiss and Italian research as too academic, Shell had turned their attention to Norway, to more practical research in support of projects such as the laying of a pipeline across the Norwegian trench.