The Crystal Ball, by John William Waterhouse (1849–1917)

Are Rebreathers the Future of Diving?

— *A Report on the State of the Rebreather Nation*

Text by Michael Menduno
Photos by Rosemary E Lunn, Mark Powell, Barb Roy, Peter Symes

A rebreather dive begins before you enter the water. You strap on the machine, put on your mask, or pinch your nose, and "pre-breathe" the unit for five minutes while monitoring the sensors and heads-up display (HUD) for any signs of trouble. It's usually one of the last checklist items to complete before commencing the dive depending on the rebreather. Many divers find that pre-breathing is centering, like a moment of Zazen. You can feel your connection to the machine as your lungs rise and fall in counterpoint to your rebreather's counterlungs. Resistance is futile: you and the machine are one. The quiet hiss of the solenoid valve firing focuses the mind and everything settles down.

Many industry experts say that the paradigm for rebreathers is about to change making them more widely available for recreational divers.

It's the silence that first catches the attention, as you descend in the water column. There are no noisy bubbles. You can hear the soft whisper and rhythm of your own breathing and almost detect the beat of your heart. You relax and slow down. Often divers don't notice that they are breathing warm moist "air" (actually a dynamic mix of nitrox or heliox) until sometime later in the dive. You feel warmer in comparison to scuba and not dehydrated.

"It's like returning to womb of the mother," said wildlife photographer and expedition leader Amos Nachum describing his early rebreather dives. To the wildlife around you, you're no longer a noisy outside intruder but just another part of the food chain, so you can get up close and personal.

Couple this enhanced communion with the "silent world" with greatly extended bottom times (a combination of gas efficiency and minimizing inert gas uptake), and you can see why rebreathers have so much appeal.

Want to spend three hours exploring a reef system on a "no-stop" multi-level dive from 60 to 100 feet? Make two 90-min plus boat dives without changing out your cylinders? Or spend an hour at 100 feet with minimal decompression. You can!

Unlike open circuit scuba, rebreather dives are limited by the capacity of the scrubber—a canister containing absorbent material that removes the CO_2—not gas volume, and typically provides up to 3-4 hours of dive time depending on your metabolism and the water temperature, essentially independent of depth.

As a result, the prospects of "running out of gas," the number one factor in open circuit scuba fatalities, is no longer an issue. Nor is the stress of watching a dwindling SPG or buddying up with a heavy breather. For tech divers, the advantages of a rebreather are even more pronounced, enabling them to truly go where no open circuit diver has gone before.

A changing rebreather paradigm

Divers are hearing a lot more about the virtues of rebreather diving in the media. PADI Inc., the self-proclaimed "Way the World Learns to Dive," is marketing a series of rebreather courses aimed specifically at recreational divers, and is supporting the effort with "Tec Xplorer Day" events and try-dives to promote rebreather div-

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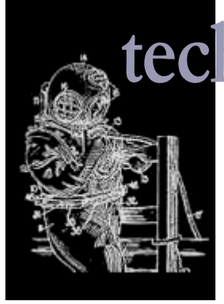

BARE 2013 participant test diving an Evolution rebreather by Silent Diving

It's the silence that first catches the attention as you descend in the water column. There are no noisy bubbles.

PETER SYMES

ing. They also announced a series of technical diving rebreather programs.

Though other training agencies have offered "recreational" rebreather courses for some time, none have PADI's sheer reach and marketing clout with more than 135,000 instructors and divemasters, and nearly 6,000 affiliated dive centres worldwide. It is expected that they will significantly expand the market for rebreathers. Call it a "Rec Revolution."

Since their introduction to sport divers more than a decade and a half ago, rebreathers have become an essential tool in the technical diver's arsenal. In many respects, they represent the ultimate fulfilment of the "technical diving (or mix) revolution" that began in the late 1980s, enabling divers to go deeper and stay longer than they could with conventional air-based scuba.

Many industry experts say that paradigm for rebreathers is about to change making them more widely available for recreational divers.

Today, rebreather diving represents the fastest growing segment of the tech diving market, and in some place like the United Kingdom, you're likely to see more divers sporting rebreathers than sets of doubles.

Though a few well-healed recreational divers have purchased rebreathers, until recently, their cost, complexity, maintenance requirements and poor safety record have limited their use primarily to tech divers who needed their extended range capabilities.

But now, with the advent of more user-friendly next-generation machines, a decade and a half of industry training experience, and the rudiments of a global infrastructure in place to support rebreather travel, many industry experts say that the paradigm for rebreathers is about to change making them more widely available for recreational divers.

PADI's recreational rebreather protocol is based on two important prerequisites. First, that the rebreather conform to their new "Type R" specification making them "suitable" for recreational diver use. For example, a Type R rebreather helps automate the required pre-dive checklist process, and will turn itself on if the user forgets. They also won't operate without a scrubber canister present or the gas turned off and they have a built-in open circuit bailout valve in case of emergency. Second, that diving operations are limited to "no-stop" diving within the recreational envelope of 130 feet.

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Advocates say that PADI's entry into the rebreather market will help revitalize sport diving and increase the number of new divers while raising the bar on rebreather training. They compare recreational rebreathers to the introduction of snowboards in the then stagnant skiing industry in the late 70's. Though resisted at first, the technology attracted needed young people to the sport which then grew by a factor of 60 times over the next 25 years.

"You're too old if you think rebreathers won't work for recreational divers," said U.S. Navy Commander Joe Dituri, who serves as the vice president of the International Association of Nitrox and Technical Divers Inc. (IANTD) and trained his 15-year-old daughter to dive a rebreather. "Kids are smarter on electronics than we ever were, and they are goal oriented. I say get on board now or be left at the gate." [Dituri's views don't necessarily reflect those of the U.S. Navy].

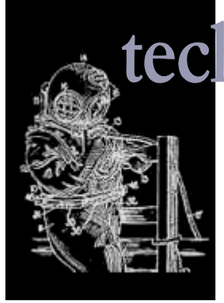
However, many industry watchers are concerned that with their operational complexity and poor safety reputation, the benefits of rebreathers may simply not justify the risks for recreational divers. Others like Technical Diving International (TDI) founder and former Uwatec CEO, Bret Gilliam, whose company marketed the Dräger Atlantis semi-closed rebreather to recreational divers in the late nineties before the machines were discontinued, says that rebreathers can meet the standard of "acceptable risk" if proper screening is put in place to weed out the unqualified participants.

Advocates compare recreational rebreathers to the introduction of snowboards in the then stagnant skiing industry in the late 70's.

Not so forgiving

"Just because you can afford one doesn't mean that you possess the background of experience and skills to use a rebreather," he said. "The overwhelming majority of sport divers are better off on open circuit, which is far more forgiving."

But there is also trepidation. As the CEO of one rebreather manufacturer explained, "I am worried that it [PADI program] will result in a plethora of



Rebreathers do not eliminate the need for open-circuit scuba. In fact, you and your team need to carry, or stage all the open circuit gas required to bail out at the worst possible point in the dive.

dead dentists, which will set the rebreather business back just like the Electrolung in late 60's." [Beckman Instruments pulled the $2,500 Electrolung—the first electronically-controlled closed circuit rebreather—from the sport diving market in 1970 after a series of high profile deaths.]

The work of (re)breathing

For all their benefits, rebreathers require more work and discipline than open circuit scuba. The late Dr Ed Thalmann, for senior medical director for the U.S. Navy Experimental Diving Unit (NEDU) who wrote all the physiological specs for U.S. Navy breathing apparatuses, once described a scuba regulator as the steam engine of diving. "They've been honed to a high degree and are incredibly reliable. By comparison," he said, "a rebreather is like a space shuttle." Though Thalmann's analogy might seem far-flung, many people compare rebreather diving to instrument flying a small plane; the diver is in essence depending on his or her electronics to maintain and manage an artificial life-supporting atmosphere.

Rebreathers require more work and discipline than open circuit scuba.

Subtle ways

Unlike open circuit, where failures like a free-flowing regulator, burst O-ring, or simply forgetting to crank open a tank valve all the way is immediately obvious; rebreathers often fail in subtle ways. In fact, the user might not even be aware of the problem, particularly if they're distracted, until it's a matter of survival.

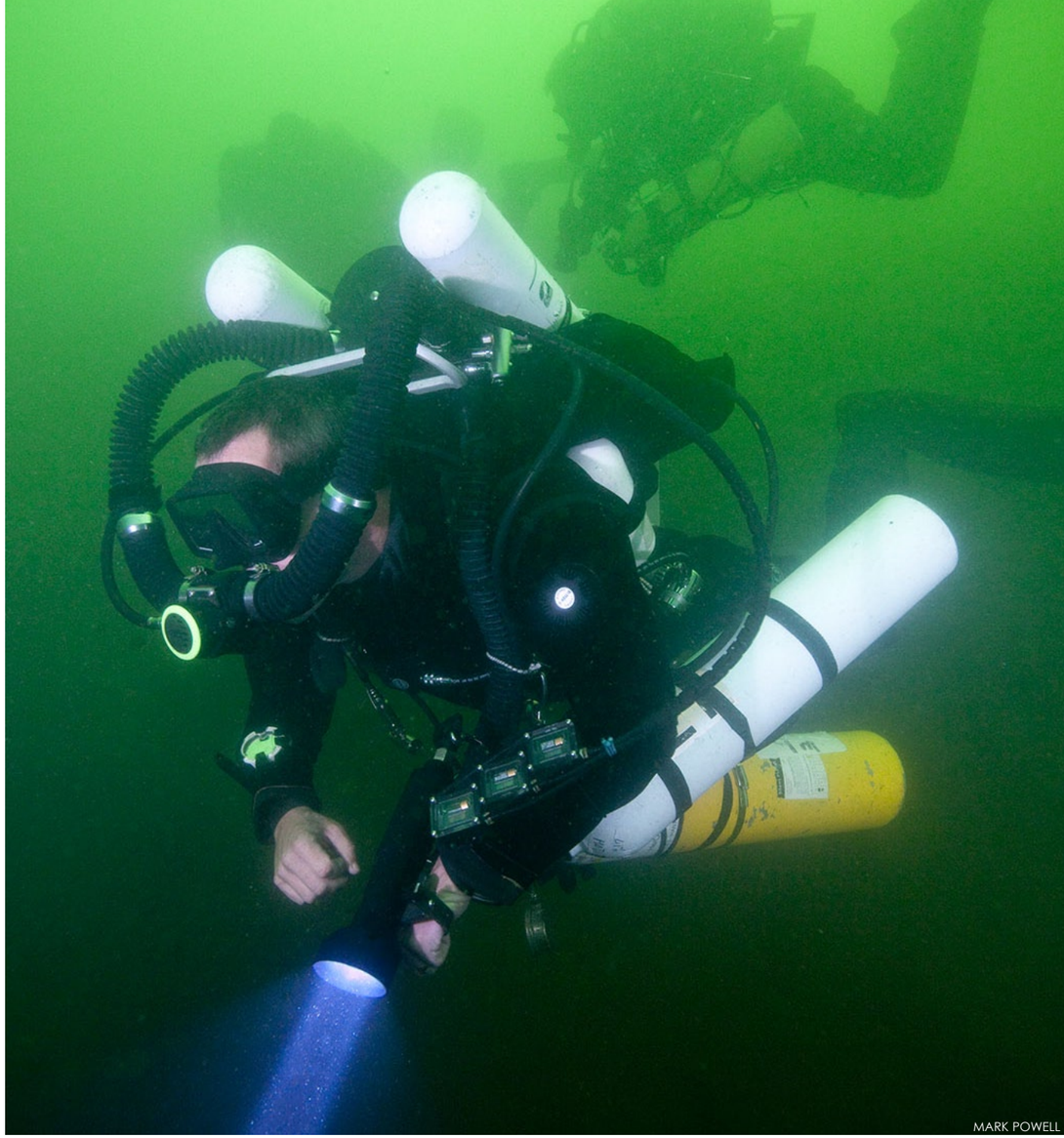
Conversely, a rebreather gives divers many options to solve any problems that arise at depth and either continue or abort the dive.

Though today's rebreathers are much more reliable than those of a decade ago, probabilistic analysis suggests that a rebreather, which is an electro-mechanical life support system, is still 20-times more likely to fail than a set of doubles due to their complexity.

However, incorporating redundant systems, e.g. adequate bail out, can mitigate this risk.

Then there is the on-going pre-dive and post-dive maintenance requirements, i.e. completing the 20-50 items on a pre-dive checklist, which includes a series of pre-dive tests and somewhat fewer post-dive, which can add up to a total of an hour or more of work per dive day compared to 30-45 minutes or less for conventional scuba gear.

And guess what? If you don't complete the checklist each and every time you dive, when Murphy strikes, you could find your self in serious trouble or even die.



MARK POWELL

Still need tanks

Rebreathers do not eliminate the need for open-circuit scuba. In fact, you and your team need to carry, or stage all the open circuit gas required to bail out at the worst possible point in the dive. Rebreather veterans say that too many divers carry insufficient bail-out. Some rebreather veterans say that you should plan to carry as much as 2-3 times the bail out gas volume that you think you need. "People forget that bail out gas is for themselves and their buddy," said TDI instructor trainer, Steve Lewis. "They also underestimate their bailout-breathing rate, particularly in the event of a CO_2 hit."

Finally, in terms of expense, rebreathers cost approximately 2-3 times their open circuit equivalent, though this differential is likely to decrease as manufacturers' volumes increase. Operations-wise, a dive day on the rebreather will likely cost you one and

FILE PHOTO: DEEPSEA PRODUCTIONS

a half to two times as much as scuba.

For whom the bell tolls

At least one 181 divers died diving a rebreather between 1998 and 2010. Rebreather fatalities averaged approximately ten per year prior to 2005 and about 20 per year since, and it appears more than 20 rebreather divers have died since 2010 making the total number of deaths more than 200. Many of the deceased were diving's best and brightest, and the toll on the community and particularly those who lost friends has been particular heavy. No one has counted the near misses.

To put these numbers in perspective, there was a combined total of about 100-120 sport diving fatalities per year on average in the United States, Canada, United Kingdom and Europe over the same period, which represents a large percentage of the worldwide sport diving market. (No one keeps worldwide diving fatality statistics.) On that basis, rebreather fatalities represent about 15 percent of the total each year.

But now consider that there are as many as 1-1.2 million active scuba divers in the United States alone, according to a 2007 analysis by Undercurrent (again there are no hard numbers) but likely no more than 10-15,000 rebreather divers worldwide. This would suggest that the fatality rate for rebreather diving is significantly higher than its open-circuit counterpart.

Divers are killing themselves because they made mistakes in their maintenance and pre-dive checks, or during the dive. Unfortunately, rebreathers require diligence to detail and are not very forgiving

In 2011, Australian hyperbaric physician Dr Andrew Fock, an accomplished rebreather diver himself, set out to estimate the actual risk of rebreather diving by collecting and analysing data from the DAN, DAN-Asia Pacific, BSAC, Deep Life and Rebreather World databases. "They're really best guest numbers," explained Fock, who presented his findings last year at Rebreather Forum 3.0 in Orlando, Florida. "There are errors and incomplete data. We know the number of fatalities but no one knows how many rebreathers are in the field, the number of rebreather divers or how many dives they made." In other words, we know the number of incidents but not the relevant denominator.

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Rebreather instructor assists a participant prepare to test dive a Hollis Explorer rebreather during the 2013 Bay Area Rebreather Experience

Fock's conclusions? Rebreather diving may currently be as much as 8-10 times more risky than open circuit diving with a corresponding estimated incident rate of about 4 deaths/100,000 dives compared to a rate of .5 deaths/100,000 dives for scuba overall. Of course, some portion of this risk, is due to the fact that to date rebreathers have been primarily used to conduct deeper and longer "technical" dives. However, with scant data there is no way to quantify this extra risk.

Apples vs oranges?

It should also be considered, that historically fatality rates are often disproportionately high in the early phases of many "civilian" adventure sports such as flying small aircraft and hang gliding until participants are able create suitable safety paradigms; early technical diving is a case in point. Using Fock's analysis to compare rebreather diving to other adventure sports, diving a rebreather is an order of magnitude less risky than base jumping at 43 deaths/100,000 jumps, but risker than sky diving at .99, hang gliding at .86 and horseback riding at .57.

Exploding heads

Statistics like this make defence attorneys' heads explode. "Plaintiffs talk about safety statistics and try to use them to argue their case," said David Concannon, who represents the Rebreather Education and Safety Association (RESA). "But they're based on faulty statistical assumptions because we don't know the denominator.

Concannon, a diver and ex-pilot who describes himself as "CCR Diver Zero" and consequently dives open circuit ("I'm 46, thick in the middle, only in the water 12-20 times a year, and I don't take care of my equipment), won three of the five lawsuits that have been filed to date against manufacturers and agencies, and settled a third for nuisance value [one other suit is pending].

"The more I see, the more I

Using Fock's analysis to compare rebreather diving to other adventure sports, diving a rebreather is an order of magnitude less risky than base jumping

believe that rebreather diving is similar to open circuit in that there are triggers that are the cause of death. The main difference is that there are more opportunities to get in trouble with a rebreather. It's like flying a multi-engine plane, or helicopter, compared to a single engine prop plane."

Tales of a non-compliant species

Over the last year, I spoke to more than a dozen manufacturers, engineers, instructors, hyperbaric doctors, defense attorneys and explorers about the fundamental causes of rebreather fatalities and what needed to be done. Though I found differing opinions about the remedies, there was an overwhelming consensus of views as to causation. In a nutshell, though some problems can probably be addressed by human factors in engineering, the fundamental problem is operational i.e. the ability of divers to properly maintain and operate their rebreathers, and not necessarily a failing of the machines themselves.

"I've yet to do a forensic examination of a fatal accident and see where a unit failed. It's always "diver error," explained Gilliam, who has worked as an expert witness for more than two decades. "Divers are killing themselves because they made mistakes in their maintenance and pre-dive checks, or during the dive. Unfortunately, rebreathers require diligence to detail and are not very forgiving. If you, the operator, make a mistake there is very little room for error, and most divers don't recover. And that points directly to training and experience."

Leon Scamahorn, a former Special Forces diver and founder and CEO of Inner Space Systems Corp, which makes the Megalodon rebreather, or "Meg," compared diving a rebreather to packing your chute and jumping out of a plane. "If you fail to react, or react properly, the results are the same. Death by terminal velocity, or in the case of the rebreather, death by inappropriate gas mix." (Rebreather divers typically lose consciousness and drown as a result of having too little or too much oxygen or too much CO_2.) "I tell people, everything depends on your level of preparation and training," said Scamahorn.

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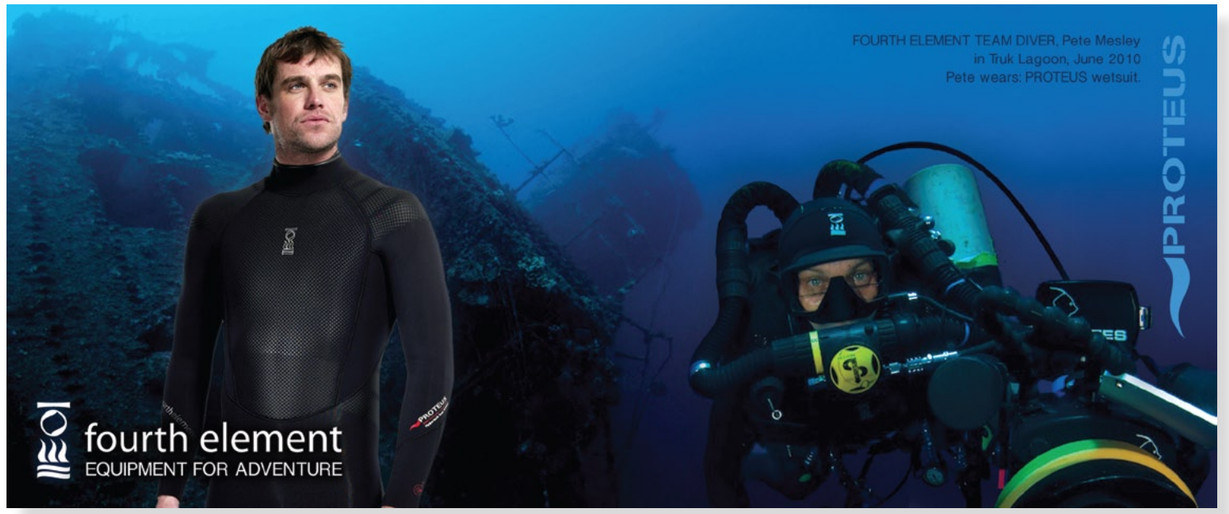
Leon Scamahorn, Inner Space Systems Corp - maker of the Megalodon rebreathers,



Causes

Reading through available accident reports is reminiscent of the kind of problems that plagued the early days of tech diving. Divers failed to turn on their rebreather (lots of these), and went hypoxic and drowned. Divers failed to open their oxygen valve, analyse their gas, and/or used a diluent or bail out gas inappropriate for the depth. They packed their scrubber canister incorrectly, left out an O-ring, or reused spent scrubber material or forgot to install their canister at all. They went diving with only two of three oxygen sensors working, or used old sensors, or old batteries. They ignored visual and audio alarms. They carried insufficient bailout gas. They were diving alone. Most of these incidents could have been prevented if divers had worked through their checklist and followed protocol.

"The problem is that people take short cuts and don't follow the guidelines and best practices," explained Steve Lewis, author and current *X-Ray Mag* columnist "They get 40-50 hours and nothing happens because the units are so well made. So they stop using their checklists. They say to themselves, I know I should, but how often does something go wrong? Of course, that's precisely when Murphy steps in."

Bruce Partridge, CEO of Shearwater Research, which builds rebreather electronics and dive computers, and is also a RESA member calls it the "normalization of deviation" because deviation from standards become normal. "It's a real problem," he said. "People go diving without having completed their checklist and nothing happens. They have significantly changed their risk, but they don't get any immediate feedback."

No longer scared

The reliability of today's rebreathers can give divers a false sense of confidence. "In the early days, the equipment broke all the time, and so we expected problems," said filmmaker, explorer and instructor Jill Heinerth. "We were scared all the time and so tended to be prepared to make good decisions when we had a failure. Now the equipment is so incredibly reliable, there is nothing to scare people."

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Jill Heinerth, filmmaker, explorer and instructor


BARB ROY

The technology also enables people to dive beyond the limits of their training and experience level. "The rebreather enables people to make expeditionary dives without the necessary operational support, and they get into trouble," pointed out Fock, who identified the Human Machine Interface (i.e. maintenance, training and high risk behaviors) as the source of most problems in part of his safety analysis work. "We found that in two-thirds of fatalities, divers exercised what could be considered high-risk behaviours [such as ignoring checklists, solo diving, or pushing limits]."

This begs the question that if the technical diving community, which is presumably more experienced, better trained and able to deal with more complex diving situations has been unable to reduce rebreather fatality rates, how will recreational divers fare?

Checklist mistress

Finding solutions is easier said than done. "We are a non-compliant species," lamented Heinerth who has been called the 'Checklist Mistress.' "How do you change that?" She says that training is partly responsible, but more of the issue is a matter of culture.

"I know that some of my students have stopped doing their checklist. But I don't know the cure. We have to police each other. If we don't, we're liable to wind up with minefield of dead divers and more lawsuits, and it will only be a matter of time before land-owners and boat captains will no longer allow rebreathers," she said.

It may all come down to changing the mind-set of the community. "We need to get to a place where it's cool to do checklists, and people aren't afraid to say to a buddy—don't get in the water with only 2 of 3 sensors working," commented Partridge. "I really believe it's a community problem. If you're flying an aircraft, we can make a rule. If your equipment isn't working properly, you can't fly. But we can't do that with divers."

The problem is that people take short cuts and don't follow the guidelines and best practices.

The problem is compounded by the fact there is no adequate community reporting system in place at the present time and rebreather incident data, particularly regarding fatalities has become increasingly scarce as a result of an increasingly vitriolic media environment and the fear and expense of litigation. And if a lawsuit is filed, everything gets closeted in confidentiality agreements unless a trial verdict is brought forward in the public record. This raises the conundrum, "How do you improve diver safety if no one will tell you what caused the fatalities?"

Engineering in safety

Manufacturers say that some of the problems that have triggered accidents, for example, failing to turn the unit on, or reassembling a unit incorrectly, can be engineered out of rebreathers thus improving diver safety and making the machines more accessible to a wider range of divers. Indeed, that is the focus of PADI's TYPE R specification, which requires that a "recreational" rebreather have certain features to be included in their program.

Though all of the manufacturers that I spoke with have incorporated unique features and innovations in their machines—there's no doubt that rebreathers represent a dynamic and innovative mar-

Rebreathers

The question is whether the sport diving community is willing and able to make the changes needed to accommodate this technology within acceptable levels of risk.

ket—I decided to focus on three areas of innovation that seem most promising in terms of diver safety.

Automating the checklist

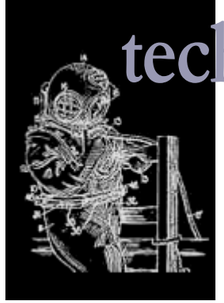
The first major area of improvement is automating the checklist process. "The aviation and auto industries have long recognized that humans are fallible and susceptible to external influences and task loading, and have embraced automation," explained Kevin Gurr, principal of VR Technology, which makes the Sentinel rebreather and is working with Hollis, which is manufacturing and distributing Gurr's latest creation, "The Explorer," an electronic semi-closed rebreather designed for recreational divers.

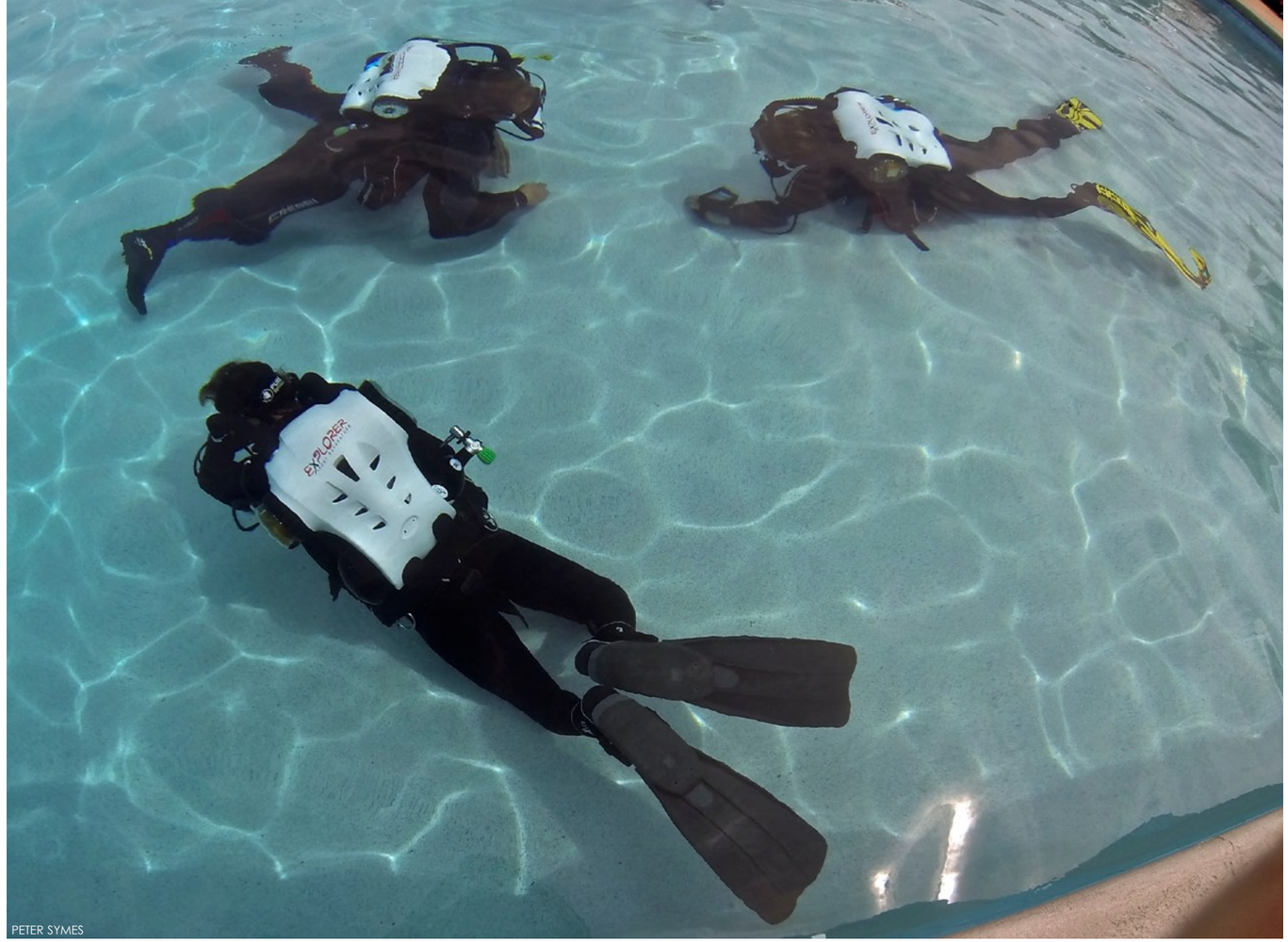
"When you turn on your car, you're actually turning on a computer, which then checks the brakes, the engine management system, fuel injection and other safety systems and tells you that it's okay to go. You don't have to remember to turn on your brakes before you drive away. We concluded that rebreathers would benefit from the same type of automation," said Gurr.

Accordingly, the Explorer, and other units like the Poseidon Mark VI, not only walks the user through the checklist via their display but makes sure that he or she completes the steps like turning on the O_2 or pre-breathing the unit, and not let the user pass until checks

ROSEMARY E LUNN

Rosemary E. Lunn prebreathing a Hollis Explorer at InnerSpace 2013 held at DiveTech, Grand Cayman





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are done properly.

The second innovation is in oxygen control. When cave explorer and engineer Dr Bill Stone and his colleagues were originally approached by Poseidon Inc. to develop a rebreather that could be safely used by recreational divers, they spent focused thinking about failure modes and concluded the most important thing was knowing exactly what the diver is breathing at any point in time, especially with respect to oxygen levels. With open circuit, a diver's breathing mix is fixed and known but with a rebreather the breathing mix is dynamic.

"One of the keys things a rebreather diver must be able to do is read their oxygen sensors and know when to trust the results," said ichthyologist Dr Rich Pyle, who co-developed the Poseidon Mark VI rebreather with Stone. "It's easy to build a system that triggers an alarm when the oxygen values deviate by some amount. The hard part is knowing when the sensors are lying. That takes intuition and lots of experience."


BARB ROY

Galvanic oxygen sensors, which measure the PO_2 in the breathing loop, are the most critical component of a rebreather, and are generally regarded as the weakest link of the system and can fail either high or low. Pyle said this led them to developing their "active sensor validation" technology: the software automatically validates the response of a pair of O_2 sensors, which are exposed to known onboard gas in one and five minute increments, and determines whether the sensors are accurate or not.

As a result, said Pyle, the electronics are able to "think better" than a well-trained diver. "With the Mark V, there were a dozen incidences where my brain and the computer disagreed on what I was breathing. In each case, when I went back and analysed the log data, I was right and not the machine," he said. "Now with the Mark VI, I had six disagreements, and the electronics were right every time. So you could say that the Mark VI thinks better than me."

Pyle said that they are close to perfecting the technology, which he believes is superior to the three "voting" sensor system used by virtually all other closed circuit rebreathers past and present: the logic being, if at least 2 of 3 sensors agree within a specified tolerance, they are regarded as correct. Jill Heinerth calls it an exciting advancement. "Without it," she said, "Divers are facing a bit of crapshoot as to what they are actually breathing."

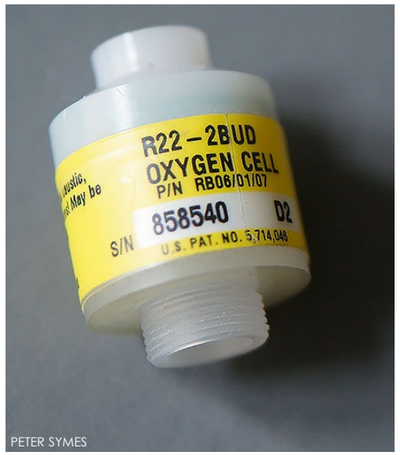
Sensing CO_2

The third major innovation has been in CO_2 sensing. Experts now say that CO_2 build-up, or hypercapnia, a result of a spent or compromised scrubber for example, is much more of a hazard than originally thought and can result in disorientation, panic, hyperventilation, convulsions, unconsciousness and eventually death. For that reason, PADI has included CO_2 sensing in its rebreather specs.

The first break through was the "temperature array," which was invented and patented by the U.S. Navy's NEDU and measures the exothermic reaction as it progresses through rebreather's scrubber canister. As such, arrays give a reasonable estimate of the life remaining during normal diving (e.g. no canister floods), but cannot respond to rapid changes in temperature, depth and workload.

As a result, some manufacturers say that they have already seen improvements in safety. Ambient Pressure Diving, the oldest and largest sport diving rebreather manufacturer, developed their "Temperature Stik" array in parallel to the NEDU. According to managing director, Martin Parker, "We've seen a dramatic reduction in incidents relating to overuse of the scrubber since we introduced the Stik. "There's something very comforting about being able to see your scrubber working properly, and we've developed it to give the diver warnings of high PCO_2 to give them plenty of time to ascend and bailout."

The second break through is due to Gurr at VR Technology who developed the first onboard gaseous CO_2 sensor, which measures the PCO_2 in the loop. VR uses the sensor in conjunction with a simple (scrubber) timer, a metabolism monitor (which measures canister loading based on O_2 consumption), and a temp array, which each measure slightly different variables. VR offers the CO_2 profile package as part of the sentinel. It will also be available on the Hollis Explorer. "Profiling the CO_2 removal system is complex



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Posedon MKVs lined up and ready for a class

because there are several components including valves, the absorbent itself and the seals," Gurr explained. "As a result, the sensing method must be multi-faceted." The ultimate solution he says is a sensor that would measure end-tidal CO_2 at the mouthpiece. "And yes, we are working on it." [Editor's note: As this issue goes to press, Ambient Pressure Diving has introduced a CO_2 monitor. It is described in the New Equipment section in this issue.]

Automation

With increased automation and improved O_2 and CO_2 sensing in a single machine, users will be able to know exactly what they are breathing with a high degree of certainty, which should help improve diver safety. However, insiders warn the responsibility still rests with the individual diver.

"I agree you can engineer out some problems, but the user can't get complacent," said Inner Space's Scamahorn, "They have to act appropriately when something goes wrong."

Training

Though insiders say that rebreather training has improved over the last decade, there continues to be some tension between manufacturers and training agencies. "Manufacturers can do quite a bit to make their machines require less training," acknowledged APD's Martin Parker, "but I do feel there will be a harsh learning curve until the instructors get on top of the important issues and emphasize the parts of the course that will keep the diver alive."

Gilliam said that agencies need to increase their prerequisites both for instructors and divers. "I think that an overall perspective should be a wake-up call to everyone that too many instructors and divers are being turned out that are not qualified," he said. "Their experience is too limited as an initial qualifier, and that's one reason why things unravel so quickly when a problem manifests. Until the agencies wise up and put proper prerequisites back in place, we'll continue to see a disproportionate amount of deaths."

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Others say that good training is available but there needs to be more consistency. "Some of the training has become a little too personal," observed Heinerth. "Everyone runs their own courses. That may be okay for someone like me with lots of experience but what about the new instructor?" Some of the instructors I spoke to also said there is a wide range of quality in training materials, and some of it is not so good.

Many people I spoke to are excited about PADI's entry into rebreather training and felt they would help raise the bar. "PADI has specific standards and very high quality learning materials," said Heinerth. "They will force other agencies to follow suit."

Others like Steve Lewis also give PADI high marks. "I just read through the PADI Tec 40 CCR Diver manual. It was enlightening for a PADI manual, and I was impressed. By the end of Chapter One, I must have read 'If you screw up, you're going die' numerous times. The quality of the material was extraordinary."

Echoing Gilliam's point, several people expressed concern about the challenge of growing the pool of instructor trainers and instructors to serve a wider audience of divers while maintaining quality. "We'll have a problem if we, as an industry, allow the quality of instructors to dilute in order to build numbers," warned Lewis. "The instructors who fast-tracked their experience are the ones who are not prepared when Murphy comes calling."


PETER SYMES

Briefing on the MKVI at Poseidons facilities in Gothenburg, Sweden

The future of diving

From Walter Stark's first dive on the Electrolung in the late 60's, or Bill Stone's foray into the depths of Wakulla Springs sporting his first Cis-Lunar rebreather prototype 20 years later, it was inevitable that rebreather technology would find its way into the hands of so-called recreational divers i.e. diving consumers. It's a basic unstoppable paradigm of technology, whether its aircraft, trucks or computers.

Are we ready to change?

The question is whether the sport diving community is willing and able to make the changes needed to accommodate this technology within acceptable levels of risk.

Blueprint for survival

The situation is arguably parallel to the early days of cave diving where there were an unacceptably high number of fatalities. In response, the community came together to create a set of "best practices" based on accident analysis pioneered by the late great explorer Sheck Exley in his book, *Blueprint for Survival* (1979).

In essence, the community learned from diver deaths and was able to use that information to improve safety for other divers by encouraging, supporting and reinforcing best diving practices. The early technical diving community also faced significant safety challenges with open circuit mix diving and took a


PETER SYMES

Taking the first plunge. BARE 2013 participant is assisted into the pool with an Evolution rebreather by Silent Diving

similar approach with *Blueprint for Survival 2.0* a decade later.

Recently, there has been some discussion among some rebreather veterans that a similar set of voluntary "best practices" for rebreather diving, call it *Blue Print for Survival 3.0* should be created and promulgated. Codifying a set of "best practices" for rebreather diving is the first step towards creating a standards-based model.


ROSEMARY E LUNN

However, to date, no one has compiled a Blue Print 3.0.

Another approach might be to create "operational standards" for rebreather diving similar to what groups like the Global Underwater Explorers (GUE) and other DIR (Doing It Right) groups have done for open circuit diving.

That is the approach that explorer and educator Mathew Partridge, owner of Pro-Tech Dive College, Phuket, Thailand, which provides factory training for the JJ-CCR, Sentinel/ Oroborous, Megalodon and Inspiration/ Evolution, has taken with his Association of Rebreather Training (ART). More than just a rebreather-training agency, Partridge has developed a set of operational diving standards for rebreathers akin to GUE's standards for open circuit diving.

The standards include specifications for rebreather configuration, diluent and bailout selection, check lists and emergency protocols. ART also adheres to team diving. To date, ART has trained several hundred rebreather divers and conducted numerous workshops. Though the organization is still in its infancy, the work that Partridge has done shows promise for improving rebreather diving safety.

Unified team Diving (UTD) also offers a standards-based rebreather training program. GUE is currently in the process of developing a standards-based closed circuit program, which will likely be released in the next few years.

Some people argue that having operational diving standards create rigidity, and that having standards makes it difficult to incorporate new information, for example, improvements to procedures on the basis of accident analysis. Though this is potentially one of the drawbacks of having standards, how can improvements based on new information be effectively disseminated and implemented when individual divers are left to their own devices to do whatever they believe is best? Another problem is that standards-based diving is likely not applicable to all sport divers, the majority of which do not belong to a membership organization.

Nevertheless, standards-based rebreather groups may help to inform and raise the bar for others in the sport diving community to follow as they have, to some degree, with open circuit technical diving.

Nevertheless, standards-based rebreather groups may help to inform and raise the bar for others in the sport diving community to follow as they have, to some degree, with open circuit technical diving. It's not inconceivable that organizations like PADI, the BSAC or other training agencies, may eventually take a similar approach in creating their own set of operational rebreather standards to be used after the class is over.

Individuals may also form local user groups or rebreather clubs that agree to adhere to a set of rebreather diving standards. Historically, standard-based diving has proven to be effective way to improve diving safety in a variety of communities. ■

Writer and technologist Michael Menduno published and edited aquaCorps: The Journal for Technical Diving *(1990-1996), which helped usher tech diving into the mainstream of sports diving, and coined the term "technical diving." He also organized the first Tek, EuroTek and AsiaTek conferences, and Rebreather Forums 1.0 and 2.0. Menduno, who is based in Palm Springs, California, USA, remains an avid diver.*