Rebreather Roundtable

Alan Krasberg

Alan Krasberg is founder and former owner of General Diving Systems in Aberdeen, Scotland, which he sold in 1989. Krasberg started diving O2 rebreathers in 1947 at the age of 13, and one year later built his own rebreather. He ran the first commercial saturation diving operations for Westinghouse in1965 and provided mixed-gas diving tables for several companies. In 1962 he built his first Closed-Circuit mixed-gas rebreather. He designed his first semi-closed rebreathers, with topside PO2 readout, used on the Westinghouse diving operations in 1965. The Westinghouse divers logged a total of 6,000 diving hours using his design. He designed and built the first surface-loop, closed-circuit system for commercial diving, a technology still in use today. Krasberg still dives an O2 rebreather in his off-time.

Bret Gilliam

Bret Gilliam is the President and Founder of TDI, and a 25 year veteran of the professional diving industry with over 14,000 logged dives since 1958. His first experience with rebreathers was on Navy projects in 1971 and includes both mixed gas and oxygen closed-circuit military models, as well as civilian market semi-closed circuit models. He and others within TDI were asked to coordinate training curriculum for the Drager/Uwatec Atlantis I semi-closed nitrox rebreather in January of 1995. A generic diver and instructor program was developed by Gilliam and others at TDI, with manuals, instructor support materials, and unit-specific operating guidelines. Over 100 rebreather instructors have been trained by TDI to date, with several hundred rebreather divers trained and certified as well.

Peter Readey

Peter Readey is a Marine Engineering Officer and a highly experienced commercial and research diver. He has been using closed-circuit rebreathers throughout most of his diving career. Readey is founder and former director of Prism Life Support Systems. He also served as a consultant with Carmellan Research. He recently joined forces with Cochran Undersea Technology to further develop the Prism rebreather. During the development and testing phase of the Prism I Readey has conducted introductory rebreather experience dives for about 1,500 divers worldwide.

Rebreather safety and training standards are topics not often talked about amidst the hype and hoopla of press releases and product announcements. Questions like "How deep can I go?", and "When can I get one?" always seem to get more attention from the media.

Until now, DeepTech hasn't published editorial articles on rebreathers—mainly because we didn't wish to add to melee. Nevertheless, DeepTech, in our commitment to advanced and technical diving safety, recently polled several rebreather and training experts in an attempt to arrive at a consensus on which segment of the dive market rebreathers are really designed for, the safety issues associated with diving rebreathers, and training standards for both rebreather divers and instructors.

DT: What are the major safety issues regarding rebreather diving, and what is the weakest part or element in a rebreather system?

Gilliam: For semi-closed units primary considerations include accurate prediction of the actual breathing bag mix, and proper user maintenance and preparation. Probably, the hypoxic issue is foremost in my mind. But even then there are only a few scenarios where the risk exists and it's entirely predictable. To get into trouble on a semi-closed, mechanical, nitrox rebreather you have to basically be three kinds of stupid: 1) try to run air as the supply gas and pass out in shallow water, 2) forget to turn the supply gas on in the first place

DeepTech and seven industry experts take a hard look at rebreather safety issues and training standards.

By WALTER**COMPER** and WIN**REMLEY**

and pass out because the breathing loop doesn't inject fresh nitrox into the counterlung, or, 3) you can simply run the supply bottle out of gas and then pass out. So unless we get a lot of Forrest Gump candidates, I think the average diver with opposable thumbs and an IQ above room temperature will be okay.

In closed circuit rebreathers you've got a few other little twists like relying on electric circuitry and solenoids that are subject to failure in salt water environments. Or the oxygen sensor can crap-out on you. Cis-Lunar deals with these contingencies by building redundancy into their units and I like what I see from those guys. Realistically, the carbon dioxide scrubbers for short duration (less than six hours) use are really not a problem and the semi-closed units are well-configured with modern state of the art absorbents doing an excellent job.

Gurr: Training, training, training and a safe design. The weakest parts are O2 sensors and the flow set of semi-closed systems.

Readey: There are three safety issues: 1) reliable PO2 monitoring of breathing gas; 2) CO2 detection; and 3) training. The weakest part of the system is the diver. When properly maintained and dived within their system parameters most rebreathers can be reliable. We've had people approach us and ask "When is the deep set coming out? I think I'll wait for that." But to dive deep you first need to build up time in the shallow range. A rebreather is a completely different animal. You must be able to control your unit in shallow water before you consider going beyond recreational limits. For that reason the Prism II, for example, will initially be a Nitrox unit and the upgrade to a deeper unit will only be sold to people who can provide proof of Nitrox range rebreather dives and experiences, and are demonstrating a responsible approach to their diving.

Clark Presswood

Clark Presswood is a former U. S. Navy Seal, retired with the rank of Commander. He was heavily involved in scientific research at Duke University conducting experimental dives on the Navy's MK-15, closed-circuit, mixed-gas rebreather. He served 3 years at the Navy Experimental Diving Unit, and 2 years at the SEAL Delivery Vehicle (SDV) Team ONE. Presswood was the Advanced Training Officer at the Naval Special Warfare Center and employed rebreathers throughout the Pacific, Indian Ocean, and Persian Gulf in various capacities during his career.

Jack Kellon

Jack Kellon is President of The Rebreather Company (RBC). He is a saturation diver, and dive director for saturation systems. He was trained on the MK-6 and Emerson rebreathers in the early sixties. Kellon has more than 30 years of subsequent experience on open circuit, closed and semi-closed rebreathers, with considerable time spent on electronically controlled, mixed-gas units. He also has experience with surface supplied salvage and construction diving. Over the past 30 years Kellon has designed many rebreather components, plus complete helmet and rebreather systems.

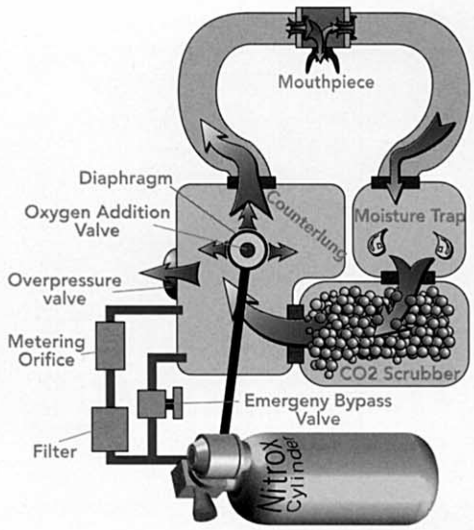
Kevin Gurr

Kevin Gurr is President of the International Association of Nitrox and Technical Divers (IANTD) in the UK and a member of the Cis-Lunar Research and Development Team. Gurr is responsible for the Cis-Lunar training activities in Europe plus he is the author of the popular Pro Planner decompression software.

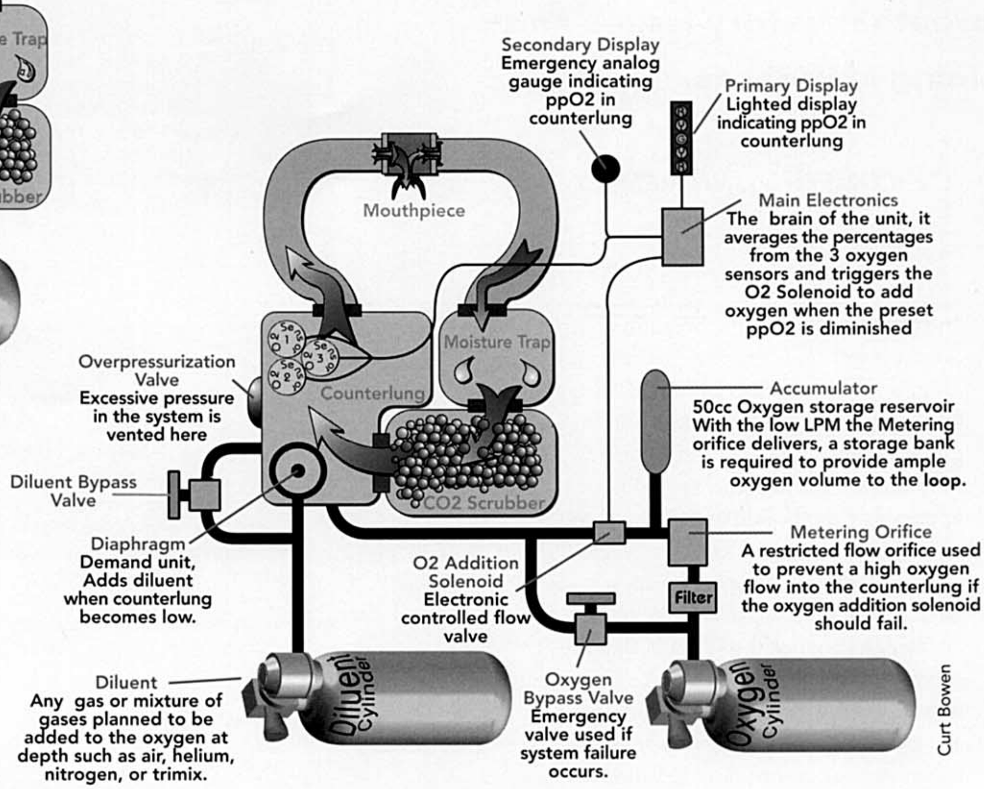
Rich Pyle

Rich Pyle works at the Bishop Museum in Honolulu while he completes his PhD at the University of Hawaii. He has been diving since 1980 and he routinely makes deep, mixed-gas, and rebreather dives in his research. Rich is a certified rebreather diver with 160 rebreather dives logged for a total of 175 hours. He has dived to a maximum depth of 420 fsw on his Cis-Lunar MK-4, plus 15 trimix rebreather dives in the range of 250-400 fsw. Rich is a respected member of the technical diving community with extensive knowledge on a wide range of diving topics. His dives a rebreather almost exclusively for the purpose of discovering new species of marine organisms in the "twilight zone" (i.e., coral reefs in the range of 150-450 fsw).

Anatomy of Semi-Closed vs. Closed Circuit Rebreathers



Semi-closed circuit rebreathers (above) recycle your exhaled gas while scrubbing out the CO2 via a CO2 absorbent. Periodically the exhaled gas is expelled into the water to "freshen" the gas. In a closed circuit system (right), the breathing gas is never expelled to freshen the mix. This requires a more rigorous measurement and control system to assure proper partial pressures of the constituent gasses in the mixture.



Presswood: Preventing hypoxia, hypercapnia, and rebreather flood-out are the main safety issues. Any possible water leakage point is a potentially weak part. Oxygen sensors, power supply systems and the respective housings for these systems have proven to be weak points on certain rebreathers.

> **You don't just slap it on and jump in; and if you do you get punished**
>
> *- Alan Krasberg*

Kellon: The weakest part is the diver. It falls upon the diver to make a rational decision on what action should be taken if a component fails. In addition, the diver is capable of making bad operating decisions that can endanger his life even if NONE of the other components fail. There is a tendency in the sport diving community to view rebreathers as just another specialty course. Even extensive open circuit experience doesn't necessarily instill the attitudes or skills necessary to become a safe rebreather instructor. Rebreather diving shouldn't be promoted to the sport diving community for activities that do not justify the additional risk.

Krasberg: The four major safety issues are: 1) lack of training; 2) lack of proper instructors; 3) lack of rigid and foolproof maintenance and setup procedures; and 4) improper equipment design enabling unnecessary diver error. The weakest part from my own point of view, is the need for rigid maintenance, procedures, and pre-dive checks. You don't just slap it on and jump in; and if you do, you get punished. I've been punished lots of times, and all but once it was due to my own lack of pre-dive diligence.

Pyle: The major safety issue is discipline. My fear is that experienced divers will become comfortable on a rebreather in a short period of time, and will want to pick up doing the same dives they were doing on open circuit right away. It's very easy to allow one's confidence to exceed one's abilities early on in rebreather diving. As with all scuba, the consequences of this are extraordinarily dangerous.

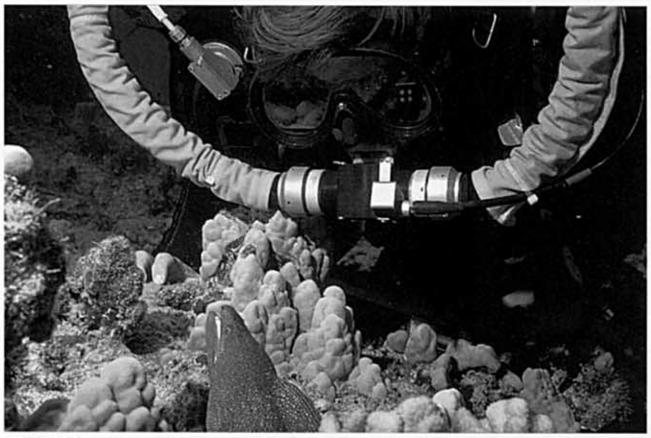
DT: Is rebreather diving for everyone? Or, put another way, do you feel comfortable recommending rebreather diving to your family and friends, and do you feel as safe while diving a rebreather as you do while diving open circuit scuba?

Gilliam: Certainly, semi-closed circuit mechanical gas injection rebreathers can be easily taught to any diver with the willingness to accept the more involved training. A certain amount of diver "maturity" is necessary, but basically you could say anyone can dive rebreathers. Personally, I feel safer with a rebreather. They're smaller, more compact, and have intrinsic advantages based on breathing a warm humidified oxygen enriched gas supply.

Gurr: Different types of rebreathers are suited to different applications and can be applicable to a wide spectrum of divers.

Readey: Rebreathers can be for everyone. The physics and gas laws remain the same, it's just the method of delivery that's different. Open circuit will always have a place, but I feel there is a possibility, in say five to ten years, of people entering the sport as rebreather divers and learning about open circuit as an emergency option but never really diving in that style. I actually feel safer on a rebreather because I typically have more time to cope with malfunctions.

Mark Mader



Rich Pyle stares down an eel while diving on his Cis-Lunar rebreather.

Presswood: At the current state of the technology and development, rebreather diving is not for everyone.

Kellon: Rebreathers are definitely not for everyone. As with any activity, some people are better at it than others due to attitude and natural skills. You need to have a genuine need for the capabilities rebreathers provide and be prepared through adequate training to deal with it. I have actually become more at home with rebreathers than open-circuit simply because I pay more attention.

Krasberg: Even with good training, I expect the fatality rate of rebreather diving to settle out higher than that of hang gliding or sky diving. If you actually NEED the equipment for silent operation, or a decompression advantage, or duration at depth, use it. Otherwise, why put up with the hassle?

Pyle: Rebreather diving is not for everyone—but neither is open-circuit diving. There are many people doing open-circuit diving who shouldn't be, and there will be many people doing rebreather dives who probably shouldn't. These aren't the only types who will die, but I think they're at a disproportionally greater risk. Rebreathers require non-water-related skills like a cool head and more than an average amount of intelligence. Above all, they require discipline. It's easier to survive scuba dives with insufficient discipline than it is to survive rebreather dives with insufficient discipline. I have told many of my friends that they would be better off with a rebreather. There are other diving friends, however, whom I would never recommend a rebreather to.

DT: What should the prerequisites be for divers taking a rebreather course and how much training should be required to become a rebreather diver?

Gilliam: With constant flow semi-closed units, we have found that the average diver with reasonable experience (100 hours or so) can be trained fairly quickly and with excellent retention. Again, there are certain learning curves to rebreathers that are only solved through direct, hands-on diving experience. Once those initial hurdles are crossed, it's pretty routine. We've found that a three to four day course with about six or eight dives produces a comfortable diver who can be expected to function independently without supervision. Obviously, the more time you get on the unit, the more proficient the diver becomes. Closed circuit is a different ball of wax and will require mixed gas training and more time in contingency situations. But again, I see those units as a tiny market right now. Cis-Lunar is really the only player and their customers are highly motivated explorers for the most part with a corresponding technical background.

All this is fairly easily defined and ordered in an instructional program but emphasis must be placed on relearning certain skills and reflexes that differ from open-circuit.

Fundamentally, if you understand the physiology and the math involved, there's really no big mystery to rebreathers in the semi-closed mode of operation. And that's the type of units we're most likely to see in the hands of the average diver this year. Closed circuit is available in limited editions and require more specialized attention to operations and initial training disciplines.

The weakest part of the system is the diver. When properly maintained and dived within their system parameters most rebreathers can be reliable.

- Peter Readey

Gurr: See the IANTD standards. They pretty much cover the bases on the topic of training.

Readey: This is a hard question to answer since people tend to progress at individual rates and it's unlikely that the recreational market would pay for the kind of extended in-water supervision currently employed by the military. Certainly a working knowledge of nitrox would be useful, but then this is something that could be taught with the rebreather. It should be possible to teach an average diver how to set up and dive a basic rebreather configuration within recreational limits in about four to six days, depending on the commitment and drive of the individual concerned.

Bret Gilliam

A diver explores a wreck while on a training dive in a TDI rebreather certification course recently held in the Bahamas

This would qualify them to the lowest level of competence, and they would then need to build up their personal experience and skill levels.

Presswood: Prerequisites should include open-circuit scuba qualification for at least one year and at least 25 open water dives . Additionally, satisfactory completion of a nitrox course should be required, unless incorporated in the rebreather course. This should normally take 2 to 3 days academic instruction plus one to two days of diving.

Kellon: The two most important prerequisites are common sense and the absence of a macho attitude. Beyond that unit specific training and a well rounded academic instruction in rebreather physics and physiology are required.

Krasberg: Get rid of the people who panic. Mental makeup is more important than physical strength. Perhaps a 4-week basic course with lots of controlled condition, simulated black-water flood-outs, and some exposure to O2 hits, hypoxia, and hypercapnia. Instruction on how to avoid hypoxia, recovering from flooding, and recovering from O2 hits are also required. After the basic course, a one-week to two-week course, depending on complexity, on the specific apparatus under consideration should be required.

Pyle: Prerequisites should be basic scuba skills, a moderate number of open-circuit dives (say, at least 50), a relatively high level of comfort underwater, a good grasp of gas physics and physiology, and above all, discipline! (not necessarily in that order).

My personal opinion is that a new rebreather diver should not exceed about 30 feet of depth without close supervision until at they reach at least about 50 hours of in-water time on a rebreather. Unfortunately, this is an unreasonable requirement for a training course. Therefore, training courses should concentrate on providing the students with an understanding of the rebreather design, physics, and physiology, as well as hammering in the discipline thing. The students should implement their own in-water, self-training protocol while maintaining a large margin for error to offset the overconfidence factor.

> **Different types of rebreathers are suited to different applications and can be applicable to a wide spectrum of divers.**
>
> *- Kevin Gurr*

DT: What should the prerequisites be for rebreather instructors and how much training should be required to become an instructor?

Gilliam: Most existing nitrox instructors are capable of handling rebreathers from the standpoint of academics. Instructors for semi-closed units can be brought up to speed in about 4 days but require more dive time on the units. Operations and maintenance training is more rigorous. Note that I'm taking about this amount of time per unit since each will have its own peculiarities and special needs. At TDI, we issue credentials based on a specific unit. If the instructor wants to teach another unit, he would need to go through additional training and familiarization.

Closed circuit, as previously discussed, is a steeper learning curve. I'd like to see instructors rack up a hundred hours or so on mechanical semi-closed units before making the jump to closed. It's really a much different technology and more complicated to assimilate without prior experience.

I'm speaking from a pretty good body of practical training experience. Mitch Skaggs, Joe Odom, Rob Palmer and I probably have more hands-on time with production level, commercial rebreathers than anyone else in the world at this stage. Some people have seemed to want to needlessly inflate the complexity of semi-closed circuit rebreathers as a way of "profiteering" on training costs. The facts are that these types of units are remarkably simple and easy to train professional instructors on.

To get into trouble on a semi-closed, mechanical, nitrox rebreather you have to basically be three kinds of stupid.

- Bret Gilliam

Gurr: Again, the IANTD standards pretty much cover the bases on instructor training.

Readey: It is important that people have experience on several different rebreathers and have built up enough time with the unit for it to be second nature to them. An instructor should also be able to recognize how a student's set-up may be affecting their diving, and be able to make adjustments, even while in the water, to make the student more comfortable. These instructor skills only come with experience, and it's important that, should an emergency arise, instructors are capable of assisting the student without having to concentrate or worry about their own equipment.

Presswood: Instructors should be qualified by a significant level of diving experience, including in-depth experience with rebreathers and perhaps some training in instructional techniques, or by successful accomplishment of a rebreather instructor course provided by a reputable organization.

Kellon: Initially, there should be few instructors because there aren't many people out there with genuine rebreather experience. I am totally opposed to the one week courses that have been taking place that make instructors out of individuals with no prior rebreather experience.

The Japanese Fieno was designed from the ground up for the sport diving community.

Krasberg:
Instructor training should be about the same as user training, except more on the specific apparatus. One group who happen to have copious amounts of time on closed and semi-closed gear to start with are the military divers. Ideally, they could train the instructors, but first they would have to learn the specific equipment. They've been through it, and know first-hand the importance of proper procedures.

Pyle: Instructors only need a thorough understanding of the specific rig design, and a good working knowledge of rebreather practice. The most important skills for rebreather diving are the kind that are learned—not the kind that are taught. The qualifications of the instructor are probably not as important as the qualifications of the student. When it comes to rebreather training, it's easier for a good student to learn from a bad instructor, than it is for a good instructor to adequately teach a bad student.

DT: Which is better, semi-closed-circuit, or closed-circuit rebreathers, and why?

Gilliam: From an efficiency stand point only, closed-circuit is clearly superior. But from a simplicity, cost, and ease of operation perspective, semi-closed wins hands down. The reality is that semi-closed is what the market is currently offering in production models at anything approaching affordable prices. Even then, prices are going to have to come down to attract much consumer interest for the general diving public. I think a retail price in the $3,000 range is about where people will be tempted to open their wallets for a semi-closed circuit unit.

Gurr: That depends on application and user experience. My view is that closed-circuit rebreathers offer less operational hassle and provide greater benefits.

Readey: It depends on a variety of factors. That's why we've designed the Prism II to be multi-mode, and operate as either. Applications such as overhead environments will probably be run closed-circuit to maximize efficiency in gas consumption and decompression management. The semi-closed mode will function as the bail-out option with open-circuit as added redundancy. This way divers will also be able to use the particular gases that are available on site. Photographers will probably also choose closed-circuit for its silence. Most recreational divers however may decide they prefer semi-closed, where that regular exhaust maintains diver awareness that the system is functioning. If a semi-closed unit is fitted with a diffuser it makes little difference to most marine life.

Prism II

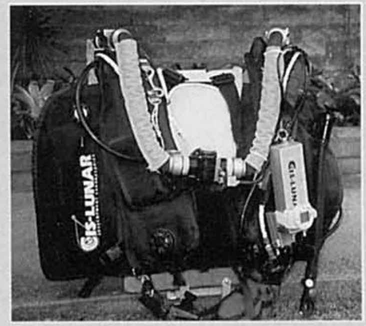
Price: $5,000 - $7,000
Type of Unit: Semi-closed and closed circuit modes
Electronics: O2 analyzer, decompression meter, CO2 detector,
Gas mixes: Nitrox (Trimix upgrade)
Maximum Depth: 150 ft
Canister Duration: 4 hrs.
Targeted Release Date: Dec 1996
Special Features: "Lifeguard" independent sensor/dive computer; warning indicators; gas time remaining display

Cochran Undersea Technology
Richardson, Texas
800-856-3483

The Frog

Price: $3,600
Type of Unit: Closed circuit
Electronics: Digital monitoring system; audio warnings for various system failures
Gas mixes: Nitrox (programmable w/O2&air)
Maximum Depth: 220 ft.
Canister Duration: 2-3 hrs.
Targeted Release Date: Fall 1996
Special Features: scrubber canister located inside chest mounted counterlung; scrubber cartridges and counterlungs are disposable

Environmental Support Systems
San Jose, California
408-227-0743.



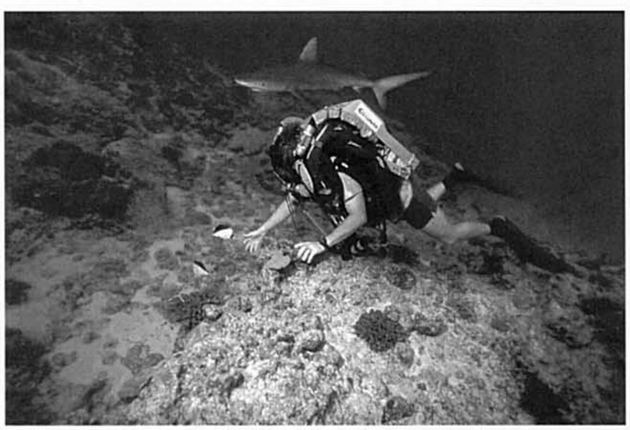
Cis-Lunar MK-5P

Price: $15,000
Type of Unit: Closed circuit with integrated open circuit bail-out option
Electronics: Oxygen and depth sensors
Gas mixes: Nitrox, Heliox
Maximum Depth: 375 ft.
Canister Duration: 6-10 hrs. at rest; 4-6 hrs when swimming at 60ft/min.
Targeted Release Date: Aug 1996
Special Features: Integrated system redundancy (3 oxygen sensors, 2 depth sensors, 3 microprocessors, multiple power sources, 3 display options); manual operation override in case of electronic system failure; backup PO2 system in case of system or power failure;

Cis-Lunar
South Lancaster, Massachussetts
508-368-0771

Presswood: I personally prefer the semi-closed rebreather concept due to the constant flow of gas, however this is a rig-dependent issue. Closed-circuit technology may evolve into very safe, reliable means of diving in time. Ideally both semi-closed and closed systems would provide redundant oxygen monitoring systems.

Gert DeCouet



A diver examines a reef while diving a Cis-Lunar rebreather. The shark is probably wondering where the bubbles are.

Kellon: Each type of equipment has its strengths and weaknesses because every design involves some sort of compromise. Generally speaking, the simplest rebreather possible that safely meets the requirements of the intended dive is the one that should be used.

Krasberg: They both have their place. Electronic, closed-circuit units have that much more to go wrong but also give you more in the feature and function column. If you need it, that's what you go with. Personally, I like the simplicity and size of an O2 rebreather. Semi-closed is enough for nearly everybody, and there are semi-closed rigs now that sound like they'd be pretty good. At least they "talk-the-talk." Fully-closed mixed-gas was my baby for a long time, but to be honest only the really hairy-chested diving requires it.

Pyle: This question is analogous to: "Which fruit is better, apples or oranges, and why?". 'Nuff said!

DT: What kind of redundancy do you recommend for open-water and overhead environment rebreather diving?

Gilliam: I'm comfortable with a simple bail-out pony bottle of sufficient volume to bring you back from the maximum planned depth. In overhead situations however, I've always liked the "rule of thirds" so you either have triple redundancy or you carry sufficient bail-out gas to provide that margin.

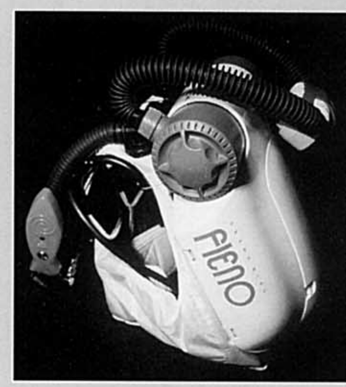
Gurr: A minimum of open-circuit bailout, plus more complex options for deco diving are required. In an overhead environment, depending on the mission, staged bail-out or a spare rebreather should be adequate.

Readey: We should at least match the redundancy level of present open-circuit diving. However with

Odyssey

Price: $ 8,500
Type of Unit: Passive Semi-Closed
Electronics: None
Gas mixes: Any used by open circuit divers
Maximum Depth: 400 ft
Canister Duration: 4-6 hrs.
Targeted Release Date: June 1996
Special Features: New model will be manufactured by an existing major dive equipment manufacturer

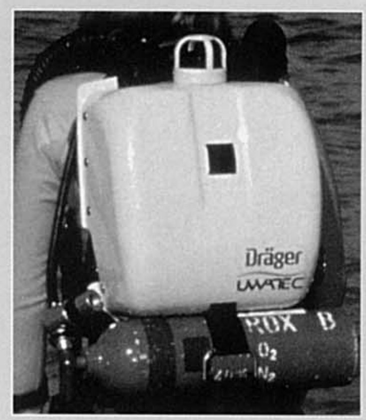
RBC
Singer Island, Florida
407-844-5100



Fieno

Price: $ 3,000
Type of Unit: Semi-Closed
Electronics: None
Gas mixes: Nitrox (EAN40)
Maximum Depth: 98 ft
Canister Duration: 110 min. (40 min. gas supply limited by cylinder volume)
Targeted Release Date: Available now in Japan only
Special Features: Disposable scrubber canister required for each dive; disposable air bag (counterlung) required every 50 dives; depth warning indicator activates at 98 ft.

Grand Bleu, Inc.
Tokyo, Japan
(03) 3796-1541



Atlantis I

Price: $6,000
Type of Unit: Semi-closed with constant mass flow and additional lung demand gas supply
Electronics: none
Gas mixes: Nitrox
Maximum Depth: 147 feet
Canister Duration: 2-4 hours
Targeted Release Date: Available now
Special Features: Comes with buoyancy compensator with integrated weight system

Dräger/Uwatec
Greenville. South Carolina
800-804-3483

rebreathers there are far more options available to the diver. Nothing happens quickly on a rebreather. There is a breathing loop with gas volume for the diver to breathe from that gives the diver time to appraise the situation and take appropriate action. Again, this comes with training and experience. No doubt, some rethinking will be needed for guidelines on how to take a rebreather into an overhead environment. The rule of thirds will apply to which section—the closed-circuit mode or the semi-closed bail-out option? Personally, if it was an extreme dive, I would probably carry a second system, perhaps on the scooter. Redundancy is a personal risk assessment that the individual has to make. Divers have to settle for something that is workable and comfortable for themselves.

Presswood: In all environments you need access to an open-circuit breathing option. A redundant oxygen monitoring system and back-up power supply for rebreathers which rely on such a system should also be used.

Kellon: As much redundancy as required to eliminate the possibility of injury due to single point failures should be used. It becomes particularly important in galvanic sensor arrays and also in electronic controls, alarms and batteries. The components of the breathing loop itself are difficult to make redundant without creating size problems. Here, an open circuit bail-out can provide redundancy. In an overhead situation I'd go for all the above plus more open-circuit bailout.

Krasberg: An open-circuit source that will get you out of trouble. On my first rig (1962), I used a semi-closed backup to the electronics plus an open-circuit regulator. In an overhead environment you need LOTS of redundancy—enough to get you home.

Pyle: Unless the rebreather is fully redundant, including at least two independent breathing loops with independent CO2 absorbent canisters, there should be enough open-circuit gas supply to safely return to the surface. For open-water dives without required decompression, this means enough to allow a controlled ascent to the surface. For decompression dives it gets trickier, and depends entirely on the particular dive parameters. Fully closed systems should have at least three oxygen sensors.

In overhead environments, at the very least, there should either be a completely independent backup rebreather, or enough open circuit gas to get back to the surface including decompression. The difficult part for long, deep decompression dives, is figuring out how much open-circuit gas to carry with you, and how to ensure that

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The most important skills for rebreather diving are the kind that are learned—not the kind that are taught.

- Richard Pyle

you can get back to staged cylinders or the surface.

DT: What type of monitoring system should be employed to measure dive profiles and/or gas quality in rebreather diving?

Gilliam: I'd really like to see an integrated active dive computer with all units that's capable of monitoring both actual counterlung oxygen partial pressure and inert gas partial pressure. Then you've really got an efficient responsive tool that's supplying the diver with all he needs to know to make intelligent decisions underwater—on the fly. Sure, it costs more money. Yeah, you can get along without it by performing manual computations, but I like removing the guess work for predicting gas contents in the breathing loop. It gives the diver more freedom and more confidence. In semi-closed rebreathers it doesn't have to give you constant oxygen partial pressure through the depth ranges by controlling the mix, it just needs to monitor partial pressure at any stage of the dive and display the information and incorporate the inert gas loading as a computer function.

Even extensive open circuit experience doesn't necessarily instill the attitudes and skills necessary to become a safe rebreather instructor.

- Jack Kellon

Gurr: Standard digital data logging—depth, time, PO2 etc. In my opinion PO2 monitoring should be employed in both closed and semi-closed systems.

Readey: I recommend that everyone diving a rebreather with inert gases has some form of PO2 monitoring—if the constant flow of a semi-closed system is restricted or disturbed by anything, then the O2 percentage will change. The Prism II has PO2 monitoring that transmits to a wrist unit and gives your decompression on the gas and the PO2 you are actually breathing.

Presswood: Redundant oxygen monitoring systems, CO2 monitoring when such technology becomes available, plus decompression computers with a high reliability algorithm.