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ARE REBREATHERS SAFE?

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Diving magazines are full of ads and hoopla about rebreathers, trying to get the sport diving community to make them their next big purchase. However, rebreathers are extremely expensive (like five figures!), and a spate of recent deaths has given them the image of being complex and dangerous.

Many divers know little about rebreathers beyond their basic function: the ability of some units to purge carbon dioxide from recycled air and to eliminate exhaled bubbles, making them a boon to photographers and those who want to approach big fish.

Rebreathers are not new. Because of their quiet operation, stealthy lack of bubbles, and the long dive times they enable, rebreathers have been used by the military for years, including extensive use in WW II. Civilian use includes underwater photography, above-ground mine rescue, and underwater scientific expeditions such as cave exploration. Their encroachment into the recreational market has been recent, although several live-aboards and a few resorts now rent them after giving divers a short training course. In places like Cocos Island, their lack of bubbles helps divers approach the big pelagics.

Rebreathers have made few inroads into the U S sports diving market. While they were on centre stage at the Diving Equipment and Marketing Association shows in 1997 and 1998, at the 1999 New Orleans show their promotion had been greatly reduced.

In the UK, safety concerns are so severe that in 1998 the British Sub-Aqua Club (www.bsac.com) announced it was prohibiting its 50,000 members from using rebreathers on BSAC dives. Although the BSAC subsequently modified its stand to enable the use of semi-closed circuit rebreathers, the use of closed-circuit rebreathers within the BSAC is still (1999) prohibited.

According to DAN's Joel Dovenbarger, DAN is aware of only two rebreather deaths in the US, one in Washington state last year (1998) and the highly-publicised death of 72-year-old Nobel-prize-winning physicist Henry W Kendell during the Wakulla 2 cave exploration in February 1999. The circumstances of Kendell's death certainly sparked rebreather controversy. Kendell was diving alone, in clear violation of both Wakulla's rules and Florida state parks regulations. After his body was recovered, the team doctor issued a report that a valve on Kendell's Cis-Lunar MK-5 rebreather was improperly adjusted, which caused him to black out due to lack of oxygen. Later, the Florida State Medical Examiner determined that Kendell had suffered a fatal gastrointestinal haemorrhage. Subsequently, the Wakulla 2 Expedition issued a statement that Kendell "died from natural causes and his unfortunate death bore no relationship to either the predive procedures that he followed that day or the dive equipment that he used. [We regret] to have rushed to judgment."

However, the rash of 1998 British rebreather deaths are cause for concern. Besides the Cis-Lunar MK-5 death at Wakulla, according to industry sources there have been four rebreather deaths attributed to the Buddy Inspiration, six associated with Draeger (www.draegerdive.com) units and one linked to a Carleton Mk 16 rebreather. Not all final autopsy reports have been completed, and the BSAC says that it is not prepared "to comment speculatively on the cause of any of the individual rebreather fatalities". But one conclusion is obvious: according to Martin Parker, owner and managing director of AP Valves, which manufacturers the Buddy Inspiration rebreather, as of February 23, 1999, the statistics stood at 4 Buddy Inspiration deaths out of 4,000 Inspiration rebreather hours dived. Whatever the cause, statistically this is an incredibly high rate.

Manufacturers such as Carleton (www.carltech-marine.com) and Inspiration defend their products but are not permitted to comment on the deaths until after the autopsy reports have been filed. However, industry spokesmen did tell *Undercurrent* that the Royal Navy had informally reported that some of the deaths are due to natural causes, and these spokesmen also said that preliminary reports in other incidents pointed to "the user making fundamental mistakes with regard to basic equipment assembly, set up, or monitoring". Still, if deadly errors are this easy to make, shouldn't users have cause for concern ?

Rebreather models vary considerably. There are variations between computer or mechanically controlled units and single mix or multiple gas units as well as basic design differences between closed and semi-closed circuit rebreathers. (Closed circuit units totally recirculate the breathing gases, keeping the proportions of the gases in balance by employing a sensor to add oxygen when it falls below the specified level and using a scrubbing material to absorb and remove excess carbon dioxide. They eliminate exhaled bubbles except on ascent, when they release the expanding gases to stabilise pressure on the breathing loop. Semi-closed circuit units, on the other hand, only recirculate part of the exhaled gas and discharge the rest with each breath. Oxygen levels are maintained by a fixed supply of compressed gas each minute. However, increased exercise can induce anoxia when the oxygen supply becomes inadequate.)

Units have a wide scope of possible mechanical problems ranging from flooding the breathing loop to maladjustments in the sensors that control the gas mix. Maintenance is involved and pricey, especially with

models that incorporate oxygen sensors. The training required to use rebreathers safely is far more extensive than, say, training for Nitrox certification. Because of the wide variation between models, there are substantial differences in training programs. Charges of inadequate training and cavalier attitudes toward rebreather usage have been bandied about extensively in explanation of the recent deaths.

Rebreathers have also been associated with a wide range of possible medical problems, any one of which can precipitate a serious dive emergency. Sudden depth changes can stymie rebreather electronics: a quick ascent, especially one where a diver is working against a strong current, can result in oxygen dropping below safe levels. An abrupt descent can cause the opposite problem. There are added risks of hyperventilation and carbon dioxide build up as well as unique decompression sickness considerations for closed circuit and semi-closed circuit systems. Oxygen toxicity (convulsions) is possible at any depth.

While official confirmations of cause of death have not been released in many incidents, some unconfirmed reports have pointed toward natural causes, operator error and inadequate backup systems. The fact that accidents seem to occur at different stages of the dive, some on the bottom, some on ascent and some on descent, makes it hard to spot a trend, although in some instances the suspected cause of death has been oxygen poisoning. Unconfirmed reports regarding problems with units recovered after fatal or near fatal accidents have also been varied, with reports mentioning recovered units in which the oxygen was turned off, units which did not have an open-circuit bail-out fitted and units which were not in "dive mode" when the diver entered the water, a situation that reportedly would make it impossible for the user to control the oxygen level.

Many deaths have reportedly involved divers with extensive opencircuit scuba experience but only minimal rebreather training and experience. AP Valves, manufacturer of the Buddy Inspiration (<www.apvalves.com>), has reportedly begun offering additional free training to all owners. Unfortunately, the question of how much training is enough has yet to be definitively addressed by the industry. Manufacturers require training when units are purchased, but there are no industry-wide training requirements and little agreement about either how much training is necessary or what constitutes safe rebreather design. Issues of how much redundancy to build into units, what sensors and displays should be included, and whether control systems should be computerised or manual have been left up to manufacturers and purchasers.

Cost is certainly a factor. For example, it is hard to fault the triple redundancy built into the CisLunar MK-5P and the company's training requirements are extensive (to purchase the unit, they require a 7 day basic training course that qualifies divers to use their MK-5P to a maximum depth of 165 ft [50 m]), but the $17,500 price tag, which does not include the cost of training, is hard to swallow. (For more info on CisLunar, see <www.cis-lunar.com>.)

While some may view the BSAC response to the UK deaths as alarmist, it is certainly a fledgling effort to set initial industry-wide standards, albeit conservative ones. The BSAC's current position on rebreather use permits only semi-closed circuit rebreathers using Nitrox (no pure oxygen rebreathers are permitted); users must carry an open circuit bail-out and dives cannot exceed 40 m. The BSAC's recommendations for rebreather users on non-BSAC dives are less stringent and appear aimed at the identified problems: get comprehensive training; follow manufacturer's recommendations for preparation, maintenance, servicing, and operation; gain progressive shallow-water experience before attempting deeper dives; stay above 50 m; use only air, oxygen, or Nitrox; and do not dive alone.

Experienced divers have spent years buying new pieces of equipment and sticking them on their backs, but using rebreathers takes more than a little getting used to. Because buoyancy and exhalation are so different from open-circuit scuba, there's enough of an "unlearning curve" that some instructors actually claim that novice divers may have an advantage in mastering rebreather use. Given the units' complexity, the deaths of several experienced divers, and such extensive differences between rebreather models that you cannot switch from one to another without additional training, there is plenty of reason for caution. In fact, that is a concession that even manufacturers are making. Martin Parker offers this succinct advice: "The diver needs to change his open-circuit thinking and remember one thing — you do not breathe from the loop unless you know what you are breathing".

Diver Barry Lee Brisco offered this summary of the problem from September 1998's "Rebreather Forum 2.0" organised by Michael Menduno in Redondo Beach, California:

"At the top of the agenda was the fact that although extensive training is mandatory when a rebreather is purchased, there are no industry-wide training standards in place, [a situation] reminiscent of the fledgling dive industry forty years ago .... Training standards are complicated by the fact that rebreathers vary significantly in design. This is in contrast to open circuit scuba, where from the diver's point of view, one regulator is used like another: air on, purge and go. Try that with a rebreather you have not been trained on and you are more than likely to end up a fatality statistic."

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