call it

"High-

$PIO_2 = P_T \times FIO_2$

By R.W. Bill Hamilton, PhD.

A new category of diving is taking shape in the recreational diving world that sparks considerable controversy, and is a cause of great concern. This, in general terms, is diving deeper and staying down longer than the traditional limits. Although by no means new, for many years it was a cause for concern more than controversy. There was general agreement that it was surely dangerous, was not approved by anyone, and one could say with a clear conscience, "Don't do it." Now methods are coming along that, for the price of extra effort, make it possible to extend both depth and bottom time with what is regarded by some as an acceptable degree of risk, and in comparison with older methods, some tempting efficiencies.

This article describes the new technolog, setting the stage for future articles that explore some of these methods in more detail, but it also contains a serious caveat about all this: It has to be done properly, or it should not be done at all.

Limits of Traditional Recreational Diving

Recreational diving is defined by the so-called "training agencies," the organizations of diving instructors (NAUI, PADI, etc.), as no-stop scuba diving with air, to 40 meters, or 130 feet. Many more experienced divers push beyond that envelope, either by doing longer bottom times that require decompression stops or by going deeper. Although there are often some definite objectives for these dives, they are nevertheless being done for fun, so it still comes under the "recreational" label. It does not, however, fit within the "traditional" definition. A new term is needed.

The training agencies discourage the use of the term "sport diving" because it implies some sort of competition. A colleague mentioned that he saw two young divers holding onto the bottom with their BCUs inflated, then letting go and racing to the surface. It is appropriate to discourage that sort of competition, just as it is the equally risky practice of seeing who can swim the farthest underwater in breathhold dives. Certainly advanced divers can practice their sport without dangerous interpersonnal competition, so the word "sport diver" does not meet our needs. Competition is indeed a motivation, not so much for the depth and time records—since nowadays they are limited to those willing to make exceptional efforts—but to be the first in an unexplored cave, or the first to look into a virgin wreck. "Sport" does not fit the bill here.

Two other names seem to be

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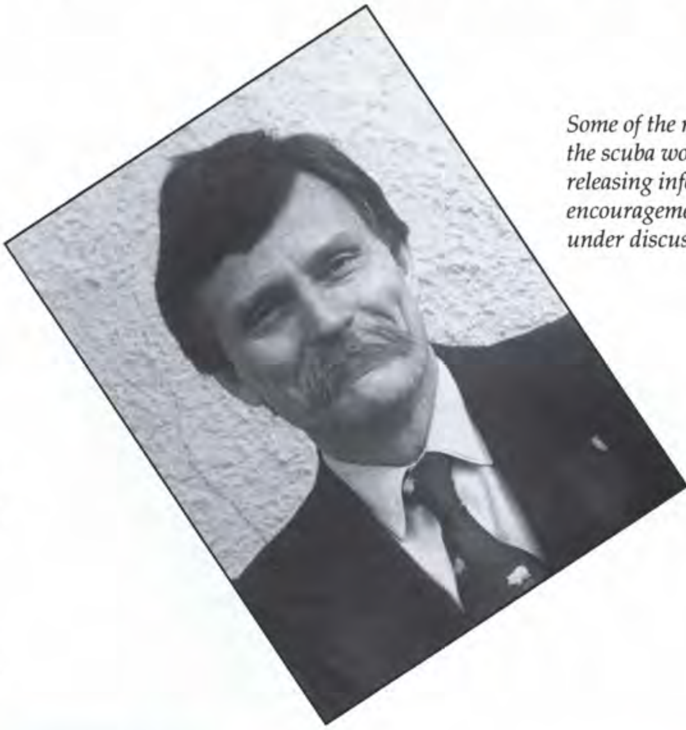
suitably descriptive. One is the possibly overused term "advanced" recreational diving, which already has many specific meanings, but is perhaps valuable for its ambiguity. This applies to a diver working outside the no-stop, 40 meter (130 feet) limit, regardless of the technique used. The other, "high tech" diving, relates to the new methods but does not include all situations, since the traditional limits can easily be exceeded with standard gear. The task of picking a single all-inclusive term can be left to others; for now, I am calling dives outside the traditional limits "advanced," and those done outside those limits using equipment other than standard wetsuits for thermal protection, as "high tech."



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Bill Hamilton

This includes the use of dive computers and new decompression techniques, dry suits, scooters, multiple or overpressurized tanks, as well as special gas mixtures. Use of dry suits and dive computers within the traditional depth and decompression limits can be considered traditional diving, although some special training is needed. While some of these "high tech" items are relatively new to recreational diving, many of the terms are old stuff to commercial divers.

The Need For Competence

Considering the unforgiving nature of mistakes in diving, just talking about advanced and high-tech diving has to be done with caution, lest it lead innocent lambs to the slaughter. Therefore this general topic has to lead off with a note on competence. We cannot proceed without such a caveat.

Somehow it seems unnecessary to warn a novice skier against trying an intentional head-over-heels flip (some of us do them occasionally without intending to, but that is another matter). But novice divers, it seems from the accident reports, do equally risky things, apparently without recognition of the risks involved. Something that may involve just a little extension beyond standard limits, if it seduces a diver into running out of air at depth, can be a great deal more risky than trying a flip on skis. Divers do these things. Therefore, allow me this bit of preaching on competence.

Many things can be done with acceptable risk, even flips on skis, by someone competent to do them. But in advanced and high-tech diving there are many things that *seem* easy and indeed *are* easy for experts, but which can involve unacceptable risk for ordinary divers. The bottom line is: divers must become competent in new diving practices before sticking their necks out.

The need for proper knowledge and training is not a new idea. When numerous commercial diving fatalities swept the early days of offshore oil exploration in the North Sea, a number of regulations were issued that addressed proper equipment and procedures. But they had no great impact on the safety record. The thing that brought about a sharp reduction in fatalities was an emphasis on competence. Although this is hard to define, it was followed by specific requirements for training, certification, and updating of divers and their supervisors. And it has worked. Many of the early accidents were human error, and while it is difficult to legislate that people must not make mistakes, it is possible to ensure that they at least know—and know well—the right way to do risky things.

All this is merely a prelude to a difficult task: to discuss what is happening in advanced, high-tech, recreational diving without encouraging people to try things they are not prepared for and thus to lead them into situations they cannot handle.

So in very general terms—you heard it here—don't do it if you do not know what you are doing.

Training, and Then Competence

What does it take to be prepared for high-tech diving? Knowledge, practice, the right equipment and good planning.

First, a diver should have knowledge of the obvious hazards to life and health that may exist in the high-tech diving environment. In addition to knowing when an oxygen mix can be expected to explode, this includes an understanding of the body's physiological limits, first in the classic "black and white" limits, but also in the duration of exposure as well as other environmental and physiological factors. Necessary knowledge includes the procedures and practices to be used—not just what they are but what they mean, the consequences of deviation, and how best to proceed when things are not going according to plan.

Familiarity with one's equipment is also critical—how it works, how to use it, how it should be maintained, and what to do when it malfuntions.

Next is practice. And I offer this as the proverbial Catch-22: before doing a new and dangerous thing, one must be highly experienced in it. The way around this double-bind is practice, something one can do at any level of experience. An aspiring advanced diver should practice all the various steps that are required, from reading a table to connecting apparatus. Practice things in parts, then link them together. Practice first with everything right, then with some variables different and finally with some things out of order. And take small steps; perhaps it is best not to try to stage bottles and oxygen in the water the first time you use your new dry suit. Consider thepilot of a high performance jet; it may take only a few months of around-the-clock training to learn to fly it, but this practice must go through many stages before real proficiency is achieved. What some world-class divers do is every bit as challenging as flying "Top Gun"; divers have a different task, but they will be just as dead if they screw up.

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Much of the high-tech in high-tech diving has to do with equipment. It need not be the most expensive, but it has to be right for the job. Know that it is right, and know that it is working and in good shape. Pilots may not take their own planes apart, but they do have to know when the aircraft needs fixing. Likewise, whether or not you design, build, or maintain your own dive gear, you do need to know how to tell when it is—or is not—right.

The last item on this list is planning, but it may be first in importance. All modern divers get some training in dive planning, and let us hope that they all use it. Planning a high-tech dive is no different in principle, but it can be a great deal more complex. Not much more needs to be said here, just be sure to make planning a fundamental part of every dive.

Getting The Technology

It is one thing to instruct new high-tech divers on the importance of learning, it is something else to provide the necessary information.

Likewise, preaching about "the right equipment" does not make it available, nor does it define what is needed. How does one go about getting the information—the knowledge—to do advanced and high-tech diving?

There is no easy way. Some of the most experienced leaders in the scuba world are dead set against releasing information—let alone encouragement—on the diving methods under discussion here. And they are right. The word-of-mouth network that gives someone just enough information to get started but not enough to do it right, is extremely dangerous.

Proper textbooks and courses are hard to come by for several reasons. First, most recreational divers shouldn't consider advanced, high-tech diving because they cannot—or will not—get the necessary knowledge and training to do it safely. Second, those who train divers as a profession don't want to add to their own woes; and the average instructor seldom has the specialized knowledge anyway. Third, the scientific diving community, who, while diving professionally, generally use recreational diving practices; they are not eager to see an excess of recreational diving accidents threaten their programs. A final point is perhaps the most important, things are not well enough developed that a crisp textbook can be written; we basically do not know as much about this as we would like. Even so, "state of the art" does exist, and because high-tech diving is here to stay and is going to continue to be used, books and courses will become available in time. Several university diving programs are beginning to move into advanced diving practice; standards are being developed; and the documentation is slowly taking shape.

Organized programs are another approach. At present, virtually all of the high-tech divers are individuals working alone. Each has his or her own equipment and procedures, maintenance, and planning practices; only when diving with partners will he/she follow the same dive profile as someone else. So in organized groups, individual divers can follow the group's practices and can gain experience with risk reduced to the practical limit. This is not widely available yet, but it is coming.

What does it take to be prepared for high-tech diving? Knowledge, practice, the right equipment, and good planning.

Another tried and true way to learn new tricks is from someone who already knows how. How do you know when your expert is telling you the right things? Obviously you check his track record, find out how he got his training, and how he is regarded by the community.

Our contribution is to offer more specific details in future articles, including a review of the activities being carried out by high-tech diving programs.

Risk

At some point, it is necessary to discuss risk. Diving is a risky enterprise. Like anything else, the risk involved is directly related to the style of the practice. Some automobile drivers go their entire lives without accidents, others have them all the time. Most of the factors that influence driving risk are well-known, with attitude—the strong desire to drive safely—being the most important item. Diving is the same, and the consequences of an accident—a loss of control—are just as serious as in driving. In a recent talk on fitness to divers, Dr. Fred Bove said, "The first guy to be eliminated should be the one who runs out of gas on the freeway." Running out of gas is more serious in diving than in driving, but the point was made. The guy who runs out of gas or suffers frequent fender benders has no business in high-tech diving.

There is no such thing as perfectly safe diving, any more than there is a decompression table with a true zero-bends incidence. The only way to be perfectly safe underwater is to stick to cold showers. But diving can involve an acceptable risk. Recreational diving, as currently practiced, has less risk than many other activities, both sport and occupational, and the risk is acceptable to most. Advanced high-tech diving will involve a higher risk than routine diving, but the risk can be kept within acceptable limits by having the right attitude, and by following guidelines like those given above. If you do not intend to do it in a safe way, then for goodness sake don't do it at all.

Experience deserves a special emphasis here. Whether they be metallurgy or medicine, practices that work on numerous occasions are generally regarded as "acceptable." This is certainly the way decompression tables become validated, and other diving practices might follow the same path. Although this is a complex issue, since real depth of experience is generally lacking, the principle holds.

An Overview of Current High Tech Diving Practice

For those who have paid their dues and bravely read the sermon, it is now time for a brief discussion of what this is all about. As explained, any proper diving outside the recreational guidelines is "advanced." This includes air dives in the range of 40 to about 60 meters (130 to 200 feet)—more or less within Navy and commercial limits, and those to greater depths, in some cases exceeding 90 meters (300 feet)—which almost invariably carry too high a risk to condone. Deep air dives deserve further discussion, first to elaborate on the risks, but also to relate what has been done.

The next methods are in a category best called "special-mix diving," that is, dives done with gas mixtures other than air. Of these, the most common are two types of "nitrox" diving. Nitrox, a mixture of oxygen and nitrogen with a composition different from air, is for use in undersea habitats and has less oxygen than air. This method offers certain specific advantages, the main one being access to the depth range of from 10 to 60 meters with very long bottom times, and little or no decompression following excursions (depending on the depth of the habitat).

The term "nitrox" is also used for a mixture of air and oxygen more properly called "enriched air nitrox." This method, "EAN_x," is useful in the range from 10 to about 35 or 40 meters, and allows greatly increased bottom times with no increase in decompression time. It is being used by some university diving programs, is described in the NOAA diving manual, and is beginning to be embraced by recreational divers. There are two main hazards to EAN_x, both related to its oxygen content. Since excess oxygen is being breathed, the possibility of toxicity must be accounted for, and handling mixtures rich in oxygen is a fire and/or explosion hazard. Decompression tables for EAN_x diving can be derived from existing air tables by the "equivalent air

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depth" calculation, but some advantages can come from custom table computation.

Perhaps the most exciting of the special mix methods are "trimix" and heliox diving. Trimix involves the use of mixtures of helium, nitrogen, and oxygen that are appropriate for diving in the range of 50 to 100 meters. At the deeper end of this range, a mixture of helium and oxygen, with little or no nitrogen, is better. Trimix, or heliox diving takes considerable operational planning and preparation because of gas logistics problems and in most cases, special decompression tables are needed. Logisitics applies first at the level of mixing which takes both skill and equipment, and later at the level of breathing, since all the gas needed for a deep trimix or heliox dive cannot normally be carried by the diver.

Still another special mix method involves the use of rebreathers. These supply gas to the diver in a closed, or semi-closed loop from which CO_2 is absorbed. They are not readily available to recreational divers, but some scientific diving programs are beginning to use them, and they have been used for years by many navies. In addition to long in-water times, rebreathers offer the possibility of optimal oxygen level to gain decompression advantages. The need for redundancy in the event of system failure is a problem in some applications.

As mentioned, other high-tech items are having an impact on diving. Dive computers make variable depth diving (multilevel) and repetitive diving more accessible, albeit with meaningful risk of decompression sickness unless certain precautions are taken. Dry suits are making all types of diving more comfortable, and with proper training this is probably with less overall risk. Dry suits are essential for the long dives possible with special mixtures.

With all of these warnings issued, and all of the described parameters met, advanced high-tech diving offers the prepared, knowledgeable diver a chance to experience a realm not previously accessible to humans. And there is every reason to think—as our technology and knowledge advance—that we will be able to push the envelope even further.

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procedures must be pre-approved by the dive safety officer.

4) Sufficient air supplies must be available for each diver at the planned decompression stop depths.

5) Each diver must carry a set of decompression tables, calibrated depth gauge, pressure gauge, and watch.

6) A standby diver must be available at the surface to assist the divers or supply extra tanks if necessary.

7) A decompression chamber with trained chamber operators must be immediately available at the dive site.

8) Dives are generally limited to 130 feet or less. For dives greater than 130 feet, the above regulations are required even for no-decompression dives.

Prior to 1978 scientific diving was regulated by OSHA, the Occupational Safety and Health Administration. By this time scientists at several universities had formed an organization called AAUS, the American Association of Underwater Scientists, and had developed there own standards. Because of their safety record and demonstration of independent self regulation, they were able to convince the government to exempt scientific diving from OSHA's commercial diving standards. Currently 23 universities and institutions including HBOI are organizational members of AAUS. ✔

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Setting the Stage

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research. I taught diving in the 1950s and the students common fear was running out of air. With no pressure gauge, an no BC to assist an emergency ascent, this was understandable. In actuality, cautious use of air and
reserve valves avoided emergency ascents and most deaths were from drowning at the surface. I used to emphasize to my students the idea that they not be dependant on their Aqua Lungs. A partner of mine twice made free ascents from 165 feet to demonstrate this. Even with what we knew then, this was foolish. Today, many hold the same view with respect to shallow dives, while in deep water it is obvious that problems should be dealt with at depth, hence the use of pony tanks, Benjamin valves and other methods of providing back-up air supply. Over the last few years I've witnessed an alarming number of emergency ascents. I am equally disturbed when I find myself with a diver with a near-empty tank at the end of a dive and an alarming number of divers routinely dive this way. When we have had problems with dives on deep dives, in every instance they have employed—in one form or another—what might be called shallow water technique, technique that a modern understanding of diving physics should suggest is not appropriate even for shallow diving. Many of the ideas followed in deep dives are well-applied to shallow dives.

As a group, we perhaps are thought of as daring to venture into the open water areas that we explore, and to be diving to the depth this requires. In truth, I always argue there is both dangerous and safe diving in both deep and shallow water. ✔

Malcolm Smith, a retired photographer, now spends his free time capturing Monterey Bay's gorgonian population on film.