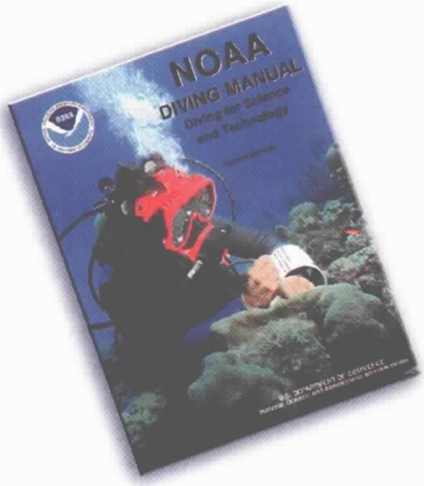

Comments on Technology Transfer in Diving: Based on a Review of the NOAA Diving Manual, 4th Edition

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Part One—Review

This is nominally a review of a 2001 publication, the *NOAA Diving Manual, Diving for Science and Technology*, 4th edition, NTIS Order Number PB99-144321INQ, and available from NTIS, see www.ntis.gov/product/noaadive.htm, or Best Publishing, see www.bestpub.com. It is available in hardcover ($89), softcover ($79), and searchable CD-ROM ($89) editions, or as a package of hardcover plus CD-ROM ($160) or softcover plus CD-ROM ($139). Be advised the CD-ROM does not support Windows 2000 or Mac, according to the NTIS website.

The first edition of the *NOAA Diving Manual* was published in 1977, the second in 1979, the third in 1991, and now this most recent edition. The notable new material in this latest edition concerns the use of "oxygen-enriched air," commonly called Nitrox, now a popular item in recreational diving as well as science diving.

There have been a number of reviews published of the *NOAA Diving Manual*, 4th Edition, and they (and we) all agree: it is a remarkable, authoritative, useful, and easy-to-use encyclopedic reference for divers of all kinds, although it is aimed at scientific divers. It is a much-updated version of previous additions, and the list of contributors and editors is a veritable "Who's Who". The contents include: history, physics, physiology, air diving and decompression, equipment, surface-supplied diving, training, dive planning, scientific diving, working dives, support systems, special diving conditions, polluted water, rebreathers, Nitrox, mixed-gas diving, saturated diving, hyperbaric chambers, hazardous aquatic life, emergency medical care, and accident management. But wait, there's more: the appendices also cover field neurological assessment, various dive tables including saturation and Nitrox, a complete glossary, a very good list of references, and a useful index.

If you want to complete your library, then also get:

- U.S. Navy Diving Manual, available as a free but large 46MB pdf file on-line (www.supsalv.org/divingpubs.html#Download)
- Scientific Diving Techniques; A Practical Guide for the Research Diver, by John Heine (reviewed in Oceanography, 14(1), by Alice Alldredge)
- Scientific Diving: A General Code of Practice, by Nick Flemming and Michael Max
- The Encyclopedia of Recreational Diving, 2nd edition, Professional Association of diving Instructors, 1996, softcover and CD-ROM [some redundancy with the NOAA Diving Manual, but a good chapter on the Aquatic Realm]

Part Two—Tech Transfer

What this review is *really* about is a short essay on where the information comes from that goes into books like the *NOAA Diving Manual*, and where it goes.

There are five major branches in the world of diving: commercial, public safety, military, scientific and recreational. In the United States the Occupational Safety and Health Administration (OSHA) either regulates these activities or gives waivers if an alternative regulatory process exists.

Recreational Diving (typified by holders of certifications from NAUI, PADI, SDI, SSI, YMCA, etc.) operates outside OSHA exactly because it is recreational. Those professionals who are instructors in the recreational domain (and might, therefore, be considered commercial divers) have a waiver from OSHA because their focus is on the student rather than some task. Also, the locations chosen for training in recreational diving are based in part on their safety and comfort rather than for some commercial application. Scuba diving instructors do not utilize construction tools, explosives, or use welding or burning tools.

Public Safety diving (firemen hunting for drowning victims, or police searching for evidence, for example) is carried out under government (federal, state, local) authorities separate from the OSHA requirements placed on industrial commercial diving. Public Safety divers may be employees of (say) a local government or are sometimes volunteers.

Military Diving also has its own regulatory system, as embodied in the Navy Diving Manual (there is a joint-service republication of the same material, to cover Army divers). The two main branches are salvage and ship husbandry, rather like commercial diving, and Special Operations, notably the Navy SEALS.

Science Diving also has a waiver from OSHA requirements and operates under the American Academy of Underwater Sciences (AAUS) guidelines, see www.aaus.org. The AAUS Manual, *Standards for Scientific Diving Certification and Operations for Scientific Diving Programs*, describes the training and certification requirements. In short, if you are going to dive as part of being on the staff or as a student at a U.S. university, then you do it under the AAUS. The table below describes (from the AAUS website) the main differences between a recreational "research diver" and an AAUS Scientific Diver. Although most science divers carry recreational certifications, that is just the entry-level certification. Full Science Diver certification includes additional training, approximately to the level of a recreational Rescue Diver plus aspects of the recreational Divemaster rating.

Research Diver (Recreational)	**Scientific Diver (AAUS)**
Practical Training Only	OSHA Defined
Training Varies With Agency	AAUS Training Standards
Variable # Of Training Dives	100 Hours Training
No Medical	AAUS Medical Required
Lifetime Certification	Must Maintain "Active" Status
Independent Instruction	Scientific Diving Program Oversite
	Emergency Training Required (CPR/FA, Oxygen First Aid)

An example of recreational "research divers" might be the group that is exploring the karst system of northern Florida using technical diving equipment. Example science divers would be university-based marine biologists studying coral spawning.

- NOAA, as a government agency, also maintains a waiver from OSHA and does its own training and certifications. Under certain circumstances, there is a reciprocal certification arrangement between NOAA and AAUS so that science divers and science work can be "crossed over." NOAA diving is science diving; NOAA hires commercial divers for commercial tasks.
- Technical Diving is a (new within the last 10–15 years) branch of recreational diving, constituting the cutting edge of equipment, depths, methodologies, and attitudes within the domain of recreational diving. It includes diving beyond the "no decompression limits," diving in caves, rebreathers and mixed gases (including Nitrox). The term "technical diving" was coined by a diving magazine to encompass those activities. There are now formal certification agencies, like the International Association of Nitrox and Technical Divers (IANTD: see www.iantd.com), Technical Diving International (TDI: www.tdisdi.com/tdi/tdihome.html), and technical diving sections of the traditional agencies, like the "TechRec" part of PADI (www.padi.com/coures/tecrec/) and the "Tec" part of NAUI (www.nauitec.com/).

  What is interesting is how several technologies and diving methodologies have started in one of these diving sectors and migrated to others.

Oxygen-Enriched Air (Nitrox)

In the 1979 (second edition) *NOAA Diving Manual*, the entire chapter on mixed-gas diving is 13 pages long, with just one page devoted to Nitrox. In the 2001 fourth edition, the mixed gas chapter is only 15 pages long, but there is an entirely new and separate Nitrox chapter that is 28 pages long!

As a reminder, the main limiting factor in much science and recreational diving is the uptake of nitrogen under pressure during a dive. Nitrox replaces some of the nitrogen in the breathing gas with oxygen, typically providing a 32% or 36% oxygen mixture instead of air at 21% oxygen. The consequent reduction in nitrogen loading can dramatically increase bottom times. For example at 50-foot depths, allowable bottom times (without incurring the need for decompression) can about triple if 36% Nitrox is used instead of air. The bad news is that the risk of oxygen toxicity increases dramatically too, so a dive with 36% oxygen is limited in practice to about 100-foot maximum depths. A dive on 36% oxygen to the usual recreational dive depth maximum (on air) of 130 feet could cause oxygen-toxicity-induced convulsions, with drowning as a possible consequence. As a result of the increased complication and risk of using oxygen-enriched air mixtures, Nitrox is considered technical diving by the recreational diving agencies and requires special training and certification for its use.

Nitrox actually began in World War II as a gas used in military rebreathers. Although it had been used experimentally in commercial diving in the late 1950s and early 1960s, it was NOAA's desire in 1977 to increase bottom times that led to their approval of 32% oxygen mixtures in 1978 and incorporation of 32% Nitrox tables in the 1979 second edition of the *NOAA Diving Manual*. In 1985, Dick Rutkowski, who had recently retired as the Training Director of the NOAA Diving Program, introduced a recreational certification program for Nitrox through a new agency, now called the International Association of Nitrox and Technical Divers (IANTD). The use has now spread through the other recreational training agencies, and is a standard course taken by many divers beyond the initial certification levels. As taught and used, the safety record is remarkable, even though about a quarter-million Nitrox certifications have been issued. For example, in 1999, of about 3 million active divers in the U.S., there were 78 reported recreational scuba fatalities. Just 3 of these involved Nitrox, and just one fatality, at most, may have been related to the increased oxygen level of the gas (statistics from the Divers Alert Network at Duke University, see www.DiversAlertNetwork.org).

Nitrox is now widely available, not expensive, and growing in use. All this in about 20 years, and directly from science diving (NOAA) to the recreational scuba community.

Alternate Air Sources

A diver faced suddenly with a loss of breathing gas supply may require an "alternate" source of gas. The 4th *NOAA Diving Manual* lists several variations of emergency procedures reflecting mission-specific requirements. Generally two options exist: other-diver assisted and self-rescue systems.

The self-rescue systems are preferred by commercial divers ("bail-out bottle" or its smaller cousin the "pony bottle") or anyone operating solo at significant distance from an alternative breathing source; a complete redundant breathing supply is carried by the diver. Also, self-rescue systems are built into many rebreather bail-out systems. Generally the operating condition drives which type is appropriate.

The recreational dive community has popularized the "Octopus" system. An additional breathing regulator ("second stage") is added to simplify sharing a single source of gas. First used by cave divers in the early 1970s, diving instructors in the late 1970s, and then adopted by the recreational training agencies in the early 1980s, the Octopus or alternate 2nd stage has become standard for most open-circuit dive operations. The system requires two basic assumptions. First the diver must be able to get to another team member, and then the team member must have sufficient reserve gas to safely ascend both divers.

The 4th *NOAA Diving Manual* has expanded information and options on alternative air systems with examples of which system is appropriate for the type of diving operations being undertaken.

Rebreather and Trimix

As mentioned earlier, the 1979 *NOAA Diving Manual* (2nd edition) provided the first wide-spread application of Enriched Air Nitrox dive operations available to the general public. By the mid 1990s use of EAN was popular by the recreational diving public. The 4th edition expands two area of diving which are growing more popular: "Trimix" and Rebreather diving. These advances have quite different backgrounds.

Rebreathers (see www.nwdesigns.com/rebreathers) work on the principle of removing carbon dioxide from an exhaled breath and recycling unused oxygen in the mix. They are very efficient systems when dealing with a limited gas supply. Reduced or little bubbling make the rebreather systems inherently quiet. World militaries have used stealthy and quiet rebreathers in some form for over 80 years. Today's revolution in electronics combined with improved rebreather technology offer some interesting future applications. Scientific divers have had limited opportunities to use military systems. However, commercially available systems have been brought to market recently. The Dräger Dolphin, for example, is a de-militarized version of Dräger's military LAR-V system. Prices have significantly dropped (as low as $1700) making rebreathers more accessible. Rebreathers are especially useful to scientific divers concerned with marine life observations and photography.

Trimix receives significant coverage in this 4th edition. Trimix is a breathing gas consisting of nitrogen, oxygen and helium used primarily between the depths of 160 feet and 300 feet. The procedures described have historical roots in recreational cave diving and technical diving techniques. Trimix expands the operational depths that open-circuit scuba or rebreathers can be used. Recreational divers have popularized the use of Trimix in several dive applications such as studying the Wakulla Spring system in Florida and volunteer divers (like the Cambrian Foundation) assisting NOAA archeology efforts on deep ship wrecks like the *Monitor* (see oceanexplorer.noaa.gov/explorations/monitor01/monitor01.html and www.cambrianfoundation.org).

Although the military can afford helium-oxygen mixtures (getting rid of the nitrogen mitigates both nitrogen narcosis and the bends), recreational and science divers usually work to tighter budgets. Trimix allows an optimum blend of the three gases so there is sufficient oxygen, not too much nitrogen, and an affordable amount of helium.

Both Rebreathers and Trimix have yet to gain wide spread acceptance, however if Nitrox serves as an historical example, the fact that NOAA choose to publish this new information will enhance the credibility of using these new tools in future recreational and research efforts.

Buoyancy Control Devices

The inflatable vest that allows the diver to achieve neutral buoyancy at any depth is a relatively new device. Derived from military diving in World War II, in a 1967 diving textbook a Mae West type buoyancy vest is described as "emergency flotation gear" for "post-dive emergency use." In the 1979 (2nd edition) *NOAA Diving Manual* a larger selection of around-the-neck flotation devices is shown, but they are still considered primarily emergency devices. They even carried carbon dioxide canisters to give emergency inflation capability. The diver's air tanks were simply held in a backpack and harness arrangement.

Meanwhile, during the late 1960s and early 1970s, European recreational divers were experimenting with a specialized buoyancy vest made by Fenzy, that carried its own small canister of compressed air that was designed to be bled into the vest as needed to maintain neutral buoyancy. ScubaPro came out in 1978 with a wrap-around jacket that carried an inflation bladder connected to the same air tanks the diver used, and integrated the buoyancy vest, the tank backpack, and the harness components into one "stabilizing jacket" or "buoyancy control device," or BCD or just BC. This revolutionized scuba diving for everyone, and is now mandatory equipment for recreational and essentially all other kinds of non-surface-supplied diving.

In Europe some still use an Adjustable Buoyancy Life jacket, or ABLJ. It is ironic that the latest *NOAA Diving Manual* (4th edition) says a BCD is "not a lifesaving device," which of course is a complete about-face from their historical derivation.

Nevertheless, we now find an essential piece of diving equipment coming from the recreational community and moving full-force to scientific, military, public service, and commercial diving.

Miscellaneous

Underwater acoustic communication systems have been essential in the commercial and public safety diving worlds, and are beginning to move into recreational diving with full-face masks. Military developments in point-to-point underwater communications have moved to digital signal processing, which may slowly make their way into diving as costs decrease.

Decompression computers have grown from an expensive novelty in recreational diving to a standard item, and now have moved into the other diving sectors. Since recreational diving rarely goes to a fixed depth and then returns—unlike much of the work in the other sectors—computerized dive tables have been a boon. However, the size of the recreational diving market has motivated considerable improvement and cost reduction in the devices, which now have moved to the other sectors as safety devices.

Hand-held navigation sonars have been a military staple, for example for navigation and mine-hunting. With simplified electronics commercial divers use them to find bottom equipment, and recreational divers use them to find the boat. With their navigational capability, scientific and research divers can much more rapidly map out an archeological site, or measure a coral reef. Some of the really fancy military sonars use an acoustic lens and megahertz frequencies to focus images into a mask-mounted display. These are now moving into the commercial sector to scan for barnacles on the hulls of ships.

Summary

Readers of *Oceanography* magazine love the ocean; divers also want to be in it. Scientific divers have found a way to be in it and make a career of it, and recreational divers get to do it even when it is not part of their job. All the diving sectors—including commercial, military, and public safety, as well as scientific and recreational—mutually benefit from the development and testing of technologies and methodologies in all the sectors. The *NOAA Diving Manual*, 4th edition, summarizes the state of the art for science diving. We expect in the future to see additional chapters added as some of the innovations now being developed in cave and other technical diving aspects of the recreational sector begin to move into the main stream. Although subtitled as *Diving for Science and Technology*, the 4th edition is a useful reference for recreational, public safety, military, and commercial diving too.