DIVER EDUCATION SERIES

Tethered Scuba Diving

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CONTENTS

INTRODUCTION

Swimming and working underwater using self-contained underwater breathing apparatus (scuba) is a standard practice in scientific diving. Accepted safety procedures for scuba diving operations generally require deployment of divers in pairs (i.e., use of the buddy system). On the other hand, commercial divers more commonly use surface-supplied (or umbilical) diving equipment and commonly deploy only a single diver to accomplish the underwater task. The diver is supported by a tender on the surface or in a diving bell.

A less commonly used mode of diving is tethered scuba diving. This generally involves the deployment of a single scuba diver who is tended from the surface by means of a safety line. Tethered scuba diving is probably one of the most under-rated and misunderstood of all diving modes. The procedures and equipment used for tethered scuba diving by some search/rescue and commercial divers are considered to be haphazard by many diving safety authorities. In the scientific diving community, tethered scuba diving has often implied attaching a rope to a solo diver using a conventional mouthpiece-style scuba regulator (hookah). There was no full-face mask security, no emergency air supply alternatives, no communications (except line-pull signals), and, generally, no specific training. Tradition, lack of state-of-the-art equipment, inadequate training, economic constraints, and narrowly scoped recreational diving influences have compromised advancement and, in some respects, safety in scientific diving.

Tethered diving has never been officially accepted by the recreational diving community in the United States. Furthermore, only a limited number of scientific divers currently use tethered scuba techniques, probably because most scientists have been trained by recreational diving instructors. Critics of tethered scuba diving include the following concerns:

- Scuba diving without a buddy is unsafe;
- The diver could be at high risk if the safety line or tether became entangled;
- The diver would not have the assistance of a buddy in the event of air supply failure or depletion; and
- The diver would surely drown in the event of loss of consciousness.

On the other hand, advocates of tethered scuba diving consider the following factors in support of the practice:

- Tethered scuba diving may only be used for selected underwater activities, not as a complete substitute for all conventional scuba diving or surface-supplied diving;
- The tethered scuba diver is not diving alone since the surface tender, in reality, functions as a buddy;
- Modern diving practices include the use of voice communications between the diver and tender, thus providing a means of constantly monitoring the diver's status;
- Tethered scuba diving operations involves less equipment, less deck than conventional surface-supplied diving operations;
- An organization can easily and economically outfit and train conventional scuba divers for tethered scuba diving;
- Use of a single tethered scuba diver is probably a safer practice for diving in very limited visibility water than free swimming scuba diving where buddy separation is more probable and underwater emergency assistance requirements such as sharing air are extremely difficult at best, if not impossible;
- Loss of air supply or primary regulator malfunction emergencies can easily be resolved by using scuba fitted with dual regulators or a compact secondary scuba; and
- If a diver loses consciousness underwater, the full face mask would prevent immediate drowning and loss of communications/line response would prompt the tender to immediately recover the diver and/or deploy a standby diver.

The equipment and procedures for present day tethered scuba diving are significantly different from those used in past years. The following conditions and limitations are recommended for modern tethered scuba diving operations:

- Depth is generally limited to 60 foot. (except in standby diver deployment emergency);
- Communications/strength member tether must be secured to the diver's scuba or safety harness;
- A full-face mask must be used;
- An emergency or secondary air supply and/or regulator system must be used; and
- The diver must surface when cylinder pressure is reduced to no less than 500 psi (300 psi for twin cylinder scuba).

Although tethered scuba diving is not considered as acceptable as surface-supplied diving by many researchers and commercial divers, it has proven satisfactory and safe for many diving scientific diving operations and for standby diver application. It has been especially useful for very limited to zero visibility shallow water research where the dive team does not have a surface-supplied system available. Under such conditions the presence of a second diver is of little or no safety benefit and may even constitute additional risk.

Tethered scuba diving has also been effectively used for extremely cold weather diving from small, open boats where the deployment of two divers would have greatly complicated logistics and increased the surface exposure time. This mode has also been successfully used for under ice diving.

Personnel

The minimum tethered scuba dive team should consist of no less than three persons — a tender/supervisor, a diver, and a standby diver. These individuals can de-

velop an efficient diver rotation plan and work safely and comfortably from a small vessel. An additional qualified individual to serve as standby diver tender, record-keeping/timekeeper, and general diver aide is highly recommended.

Any competent scuba diver can be easily trained in tethered scuba diving techniques. Establishment of an acceptable training and operational tethered scuba diving program simply requires some special equipment (in addition to conventional scuba diving equipment), a slight modification of scuba diving philosophy, and a respect for both the advantages and limitations of this mode of diving. Furthermore, most competent scuba diving instructors can develop the knowledge and skill to teach tethered scuba. Since tethered scuba diving is more likely to be applied in working operations such as search/rescue and scientific research, the instructor should have a thorough understanding of the type of diving operations for which the diver is being trained.

The trained scuba diver will have to make some adjustments in diving philosophy and technique in addition to learning to use new items of equipment. The diver will have to adjust to working alone underwater and recognizing emotional and physical security in the tender above and special equipment. Consequently, competence and experience in scuba diving cannot be over emphasized.

Tender

A tender is a member of the dive team who assists the diver in dressing, donning scuba, pre-dive equipment inspection, deployment/retrieval, and post-dive activities. While the diver is under water the tender constantly tends the dive's tether to eliminate excess slack or tension. In the event of communications unit malfunction, the tender must exchange line pull signals with the diver, keep the diving supervisor informed of the diver's status, and remain alert for any signs of an emergency.

With few exceptions, the tender should also be a qualified tethered scuba diver. This insures that the tender will have a complete knowledge of all equipment and procedures. In addition, operational efficiency is highest if all members of the team can be included in a diver rotation plan. When circumstances require the use of a non-diver as a tender, it is the responsibility of the diving supervisor to assure that the individual is properly instructed in tender duties. Ideally, non-diver tenders should complete the same training course as tethered scuba divers (except for in-water activities), plus be completely familiar with scuba and scuba diving procedures. They must also be trained in general and diving-related first aid and currently certified in CPR. It is evident that one cannot simply hand the tether to a bystander and say "Will you tend the diver today?"

Standby Diver

A standby diver is required for all tethered scuba diving operations. The diver must be fully qualified and equipped to enter the water in response to an emergency at any time. The diver shall be appropriately dressed and have equipment assembled so that he/she can don all equipment and be deployed within one minute. This means that each tethered scuba diving team must have two complete tethered scuba outfits. Ideally, a second tender is also available to serve the standby diver.

The standby diver is deployed at the discretion of the diving supervisor. The standby diver functions in a lifeguard capacity ready to render aid to a distressed diver on the surface as well as under water. The standby diver is positioned at the diving station where he/she can observe the entire operational area and quickly deploy.

Equipment

In addition to standard scuba diving equipment and thermal protection, the following items shall be included in a tethered scuba diving kit:

- Demand breathing lightweight full-face mask with communications;
- Twin 72, 80, or 100 cubic foot scuba unit with dual regulator manifold or a separate 15 to 40 cu. foot emergency scuba (commonly called a pony cylinder in scuba diving) [single cylinder scuba may be used

for short and/or shallow dives provided that a dual valve system with two regulators or an emergency scuba is included in the system];

- An over-pressure relief valve must be used on any first stage regulator without a downstream second stage;
- Submersible pressure gauge on primary regulator;
- Communications/strength member tether; and
- Surface communications unit.

Mask

From a safety and communications standpoint, it is necessary to use a full-face diver's mask rather than a conventional mouthpiece-style scuba regulator. First, proper communications is very difficult with a mouthpiece-style regulator. Second, in the event that the diver is injured or loses consciousness, the mouthpiece-style regulator can easily be dislodged and lost. With a full-face mask, even if the diver is unconscious he/she can continue to receive air.

Based on personal preference, a diver or diving group may select one of several conventional surface-supplied demand breathing masks (i.e., Heliox-18, KMB-10, DM-5 or equivalent) which have been standard equipment in scientific, commercial, and military diving for more than a decade, or a lightweight demand breathing mask (i.e., AGA, Widolf, DSI EXO-26, or equivalent).

Most tethered scuba divers prefer to use a lighter weight, lower internal volume demand breathing full-face mask rather than the heavier, more complex commercial/military masks. These lightweight masks are constructed with either soft rubber full-face assembly or a solid support frame with a rubber face seal. They are fitted with a high impact polycarbonate plastic wide-view face plate. A large, flexible nose pocket facilitates pressure equalization in the ears. The mask is secured to the diver's face using a head harness (or spider) assembly. A demand regulator is fitted to the front of the mask.

Lightweight masks do not generally include the special side block assembly for attachment of a secondary air supply common in the conventional commercial surface-supplied masks. However, a separate manifolding assembly is available which may be mounted on the scuba harness. Communications components are fitted inside the mask with an earphone positioned in a pocket in the face seal or on a head strap. An oral-nasal mask minimizes dead air space. The lightweight masks are generally less expensive than the conventional commercial surface-supplied divers' mask, and scuba divers find them to be more comfortable.

Tether

An excellent combination safety and communications line constructed of 7 mm nylon static kermantle rope with a tensile strength of 5800 lbs. is now available. The four communications wires are woven directly into the rope. This rope has the strength and handling characteristics of ordinary safety rope. Tying knots in the rope apparently has no adverse effects on the communications wires. Quick-connect electrical connectors are fitted to each end and special adapters are available. This special rope may be coiled or conveniently stored in and dispersed from rope bags.

The diver's end of the umbilical assembly is fitted with a large stainless steel snap shackle or caribiner to facilitate attachment to the diver's safety harness. This system allows any stress on the tether to be transferred to the diver's harness. The shackle is secured to the tether with an appropriate knot or a clamp that allows most of the stress to be transferred to the strength member. A D-ring is secured to the surface end of the assembly so that it may be secured at the diving station. This reduces the possibility of the tender and communicator being pulled overboard in the event of underwater stress.

The tether may be marked at 10-foot intervals starting at the diver's end using brightly colored tape or other appropriate marking system. This enables the tender to determine exactly how much tether has been deployed.

Communications Unit

A standard compact diver communicator is used for tethered scuba diving. Compact

communicators are powered by expendable or rechargeable batteries. The tender generally wears the communicator on a belt or neck strap. A combination earphone/microphone headset is plugged into the communications box. This enables the tender to satisfactorily communicate with the diver in areas of high ambient noise levels and requires less power usage than loudspeaker systems. The tender can adjust both diver and tender volume. Some models are fitted with a tape recorder connection. Generally, any surface-supplied diver communicator may be used with a tethered scuba system; however, compact models are more convenient.

A common talk or round robin system may be used to provide all parties with simultaneously open line communications, as in telephone conference calls, without operating any controls. This system involves special wiring of the mask earphones and microphone and the use of a four conductor wire to the surface. Some current model compact communications units are designed to be used as either a two-wire push-to-talk or four-wire common talk system.

Emergency Air Supply Options

The tethered scuba diver has several options for resolving an air supply depletion or regulator malfunction situation. The diver may activate a second or backup regulator, switch to a separate scuba cylinder, or make a controlled emergency swimming ascent.

Keep in mind that the possibility of air supply depletion or regulator malfunction should be absolutely minimal if equipment is properly maintained and the diver properly monitors his/her air supply pressure gauge. Naturally, the primary regulator must be fitted with a submersible pressure gauge to facilitate convenient air monitoring throughout the diving operation. Unlike surface-supplied diving, the diver is solely responsible for monitoring remaining air supply. However, as in scuba diving, the diver must be trained and prepared to resolve such an emergency.

Divers outfitted with a lightweight full-face mask will have hoses from two first-stage regulators attached to the separate manifold assembly (which may be mounted on the scuba harness.) If the air supply from the primary first stage regulator is interrupted due to malfunction, the diver may activate the second stage regulator by opening a valve on the manifold assembly. The air supply then passes through the assembly into the hose attached to the diver's second-stage regulator.

The secondary first stage regulator is attached to one outlet on a single or twin cylinder scuba dual regulator outlet manifold assembly (i.e., Sherwood slingshot valve or dual outlet valves) or to a separate scuba cylinder (i.e., 15 or 40 cu. ft. cylinder with standard valve). Many divers prefer to use a separate scuba cylinder rather than a dual regulator manifold assembly so that in the event of primary air supply depletion, the diver has an emergency air supply.

Divers working in overhead environments and locations with high risk of entanglement often prefer two scuba cylinders of equal size instead of relying on a smaller secondary cylinder. In this case two separate 70 to 100 cubic foot cylinders are mounted in a double band-harness system. Unlike the air management techniques used by cave and wreck scuba divers that involve alternating regulators, the tethered scuba diver conducts the complete dive as a single cylinder dive. The second cylinder is only to be used in an emergency. Custom designed full-face masks with dual second stage regulators and air manifolding systems are now being used by wreck and cave divers. These units show great promise for improved safety in tethered scuba diving.

Keep in mind that the secondary first stage regulator hose leads to a closed valve during normal operation, not to a downstream (or fail-safe) second stage regulator as in conventional scuba. In the event of a first stage over-pressure malfunction in the secondary regulator, the complete cylinder pressure could be released into the low pressure hose causing a rupture and subsequent loss of air supply. Consequently, this regulator must be fitted with an over-pressure relief valve.

Most scuba diving instructors and scuba divers are unfamiliar with the safety relief valves that must be installed in a low pressure port on the first stage regulator. Consult full-face mask manufacturers and commercial diving equipment suppliers for

commercial diving equipment suppliers for acquisition of these special valves.

Safety Harness/Tether Attachment

The scuba backpack and harness assembly may also serve as the diver's safety harness. This harness is equipped with D-rings for attachment of the diver's umbilical assembly and is designed to withstand a minimum of 1000 lbs. pull in any direction. Keep in mind that the scuba harness must be securely attached to the diver. In the event of an emergency, stress placed on the harness by the tender could pull the scuba from the diver. Thus, although use of the scuba backpack and harness assembly for a safety harness appears to be a standard practice, many divers do question the safety of this method. For this reason, many tethered scuba divers prefer to use a separate body harness or safety belt worn under the scuba harness for attachment of the tether.

Standard Scuba Diving Equipment

Each diver should wear appropriate thermal protection garments, a buoyancy compensator with power inflator, fins, weight belt, a sharp knife, watch/timer (for timing ascent rate) and depth gauge consistent with accepted practices in conventional scuba diving. Decompression tables may be considered optional since the supervisor/tender will monitor the dive time and inform the diver of his/her status. However, some tethered scuba divers prefer to use decompression microprocessors to monitor their dive status. Generally, each diver on a team is required to provide his/her personal diving outfit (excluding full-face mask, special scuba, tether, and communicator).

Depending on the dive depth, duration, and activity the diver may use standard single or twin cylinders taking into consideration the valving requirements discussed above for emergency or backup air supply.

Diving Procedures

Careful and detailed planning and preparation is the key to diving safety. The pre-dive activities involve all personnel and include the inspection and assembly of equipment, activation of air supply systems, and dressing the divers. This is, of course, in addition to survey of the task; evaluation of environmental conditions; selection of techniques, equipment, and divers; fulfillment of safety precautions; establishment of specific procedures; and personnel briefing.

Selection of Diving Technique

Tethered scuba diving is a reasonable compromise between scuba and surface-supplied diving. A single diver can work safely and efficiently in limited visibility water. Safety is maintained through a direct connection to the surface and voice communication. The status of the diver can be monitored at all times. Operational efficiency is greatly improved since only one diver is deployed at any given time. An efficient diver rotation schedule can be prepared to achieve maximum underwater time with minimum personnel. Scientific observations can be easily transmitted to the surface and recorded on tape. The diver's time, physical status, and emotional status can be monitored by surface personnel.

Tethered scuba diving cannot be considered as a replacement for either scuba or surface-supplied diving in all situations. The tethered scuba diver is effective within the distance limitations of the tether (generally, not more than 200 feet long) and up to a depth of 60 feet. As in scuba diving, dive duration is limited by the amount of air contained in the breathing apparatus. On the other hand, the surface-supplied diver is more effective for deeper work, under more extreme environmental conditions, and in higher risk situations. In the event of entrapment or entanglement, air supply duration is unlimited. The scuba diver is more effective for swimming great distances under water and performing tasks requiring extensive lateral and vertical mobility.

Finally, equipment costs becomes a factor. Ideally, most diving tasks performed by a tethered scuba diver could be performed by a lightweight surface-supplied diver. However, the cost of outfitting a surface-supplied diving team is somewhat higher than for a tethered scuba diving team, assuming that the team is already completely outfitted for scuba diving. A teth-

ered scuba upgrade involves purchasing two tethers, two compact communicators (or one larger two-diver model), two lightweight demand-type full-face masks, and the necessary components to convert to an appropriate independent secondary regulator/air supply system. The surface-supplied diving outfit would require additional expense for an air supply and control system and a more expensive umbilical assembly.

Tending the Diver

Tending is an art. Surface tenders should be experienced divers or persons specially trained as tenders. The most effective assistance can be given only by a tender who is familiar with the equipment, procedures, safety precautions, conditions, and difficulties that are inherent in diving. It is the tender's responsibility to see that the diver receives proper care while both topside and underwater. He/she must check all equipment before sending the diver down.

When the diver is ready, the tender helps with dressing and checking equipment, and assists the diver to the ladder or entry point. The tender handles the tether and maintains a proper strain on the diver as he/she descends the ladder. For scuba diving type entries the tender assures that the tether plays out freely.

While the diver is submerged, the tender handles the tether, maintains communications, and monitors air usage by periodically requesting pressure readings from the diver. The usual means of communications between diver and tender is by voice intercom; however, it is important that basic line signals be memorized and practiced so they will be recognized instantly in the event of intercom failure or if apparatus not fitted with an intercom is used.

In tending the diver's tether, the tender must not hold the tether so taut as to interfere with the diver's work or movements. The diver should be given 2 or 3 feet of slack when he/she is on the bottom, but not so much that he/she cannot be felt from time to time. Signals cannot be received on a slack line; consequently, the diver's tether must be kept in hand with proper tension at all times.

Line-pull signals consist of a series of sharp, distinct pulls, strong enough for the diver or tender to feel but not so strong as to pull the diver away from his/her work. When sending signals, take all of the slack out of the line first. Repeat signal until answered. The only signal not answered when received is the emergency "haul me up," and "come up" is delayed until the diver is ready. Continued failure to respond to signals may indicate that there is too much slack in the line, the line is fouled, or the diver is incapacitated.

The tender should continuously monitor the diver's underwater time and air supply pressure. He/she should inform the diver several minutes before the expiration of bottom time so that the diver can make necessary preparations for ascent. The tender keeps track of the diver's position by observing bubbles rising to the surface and informs the diver of his/her position relative to the boat/diving station. In addition, the tender must continually monitor the diver's activity. For example, the tender can frequently evaluate the diver's exertion by counting the number of breaths per minute. Experienced tenders will learn the diver's normal breathing rate. Significant increase in breathing rate may indicate potential overexertion. The tender may ask the diver to stop work, rest, and ventilate.

The tender may also have to serve as timekeeper. This job includes keeping an accurate record of the dive time and details of the dive. When possible, a separate timekeeper should be used or the timekeeper duties handled by the diving supervisor.

Emergency Procedures

The tethered scuba diver will deal with underwater emergency situations in much the same manner as a conventional scuba diver, however, he/she will not have the benefit of assistance from another diver unless a standby diver is deployed. Air supply depletion or regulator malfunction is probably the most threatening to the diver. Potential risk to the diver is reduced by the use of redundant breathing systems. The diver must also be trained in purging water from a flooded full-face mask, dealing with loss of communications, and freeing a fouled tether.

Divers entering tethered scuba diving training should already be familiar with procedures such as diver rescue on the surface, stress management, accidental ascent resulting from BC or dry suit overinflation, and so on. Naturally, proper diving procedures and common sense precautions can prevent most, if not all, underwater emergencies from developing.

Training

The criteria for this system specify that certified and experienced scuba divers should be able to complete training within less than 10 hours. This would qualify the divers to proceed to properly supervised tethered scuba and surface-supplied diving to a depth of 30 foot. Progressive acquisition of supervised experience would enable the diver to extend his/her capability to 130 feet in a fashion similar to that used for scuba diving progression by universities, research groups, and the American Academy of Underwater Sciences. Courses are specifically designed to meet the diving requirements and equipment availability of individual research groups. The author has conducted numerous experimental training courses for scientific surface-supplied diving since 1974 and has more recently introduced a tethered scuba diving program. The training program includes, but is not necessarily limited to, the following:

- Historical development of tethered scuba diving with emphasis on diving operations best undertaken using this mode of diving;
- Systems design and application philosophy;
- Tethered scuba diving team members, responsibilities, and personal equipment requirements;
- Description, selection, use, and maintenance of mask; communications equipment; emergency scuba; tether; and accessory equipment;
- Routine dive planning and procedures;
- Training experiences in all personnel assignments including supervisor, diver, console operator, tender, and standby diver. Supervisors also serve as timekeeper and recordkeeper;
- Emergency procedures for mask flooding; communications system malfunction; air supply failure; fouling; uncontrolled ascent; and other diver/surface crew distress factors; and
- Confined water and open water training activities.

Since there is presently no nationally recognized certification for completion of tethered scuba diver training, only a letter of participation or entry in the diver logbook is generally issued by instructors or institutions. Instructors of tethered scuba and surface-supplied diving are generally certified scuba diving instructors with significant scientific, military, or commercial diving training and experience.

Summary

Tethered scuba diving is an acceptable alternative to conventional scuba and surface-supplied diving for performing many underwater tasks. This mode of diving can provide the scientific diver with a method to increase economical and operational efficiency while maintaining optimum safety. The additional equipment required for tethered scuba diving is readily available from commercial and rescue diving equipment suppliers. Most competent scuba divers can be easily trained in tethered scuba diving techniques.

The tethered scuba diving procedures and equipment discussed in this article are used on a limited basis at present. As this mode of diving gains popularity among rescue and scientific divers, techniques, equipment, and procedures for safer and more efficient diving will no doubt evolve. All divers and organizations are encouraged to use this mode of diving with a high respect for diver safety.

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