MICHIGAN SEA GRANT REPRINT
MICHU-SG-76-306

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Reprinted from The Proceedings of the Seventh International Conference On Underwater Education, NAUI, Miami Beach, 1975.

MICHIGAN SEA GRANT PROGRAM - ADVISORY SERVICE -

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Readers are asked to keep in mind that this document was published in 1975 in the Proceedings of the Seventh International Conference on Underwater Education. Buoyancy compensation techniques and equipment were in a state of evoluation. Since that time there have been many refinements of scuba diving equipment, instruction, techniques, and philosophy. Some equipment used at that time is no longer available. The information presented here is for historical purposes only and should not supercede that presented in modern scuba diving instruction.

ABSTRACT

The modern scuba diver has become a slave of the buoyancy compensator. Throughout scuba diving history the diver has had to cope with variations in buoyancy due to suit compression and air usage. During the past five years scores of buoyancy compensation units have appeared on the market. Frequently manufacturers and instructors indicate that the buoyancy compensator is extremely useful for aiding the dive in the recovery of objects such as anchors from the bottom. The diver simply grasps the object and inflates the buoyancy compensator: a drastic abuse of an item of life-support equipment. Of even greater concern is the routine over-weighting of divers: especially novice divers in using the new *air-elevator* technique of diving, which also encourages individuals with little or no swimming ability to pursue scuba diving. This paper discusses the potential abuses of buoyancy compensation systems, calls for a re-evaluation of some buoyancy compensation diving techniques and suggests ways that diving might be made safer through a more conservative approach to modern equipment utilization and swimming skill evaluation.

INTRODUCTION

In many respects the modern scuba diver has become a slave of the buoyancy compensator. Throughout scuba diving history the diver has had to cope with variations in buoyancy due to suit compression and air us . age (thus, weight changes in the scuba during a dive). The average sightseeing diver strives for neutral buoyancy, almost effortless movement through the water; whereas the underwater photographer and worker needs the dual capacity of nearly effortless swimming with heavy equipment and negative buoyancy stability while photographing or working. During the past five years scores of buoyancy compensators have appeared on the market. These include a large variety of vest units, several backpack mounted units, and an increasing number of variable-volume diving suits.

THE NEED FOR BUOYANCY COMPENSATION

Most divers and diving instructors agree that there is a specific need for buoyancy compensation techniques and equipment in scuba diving. All divers are quite familiar with wet suit compression and the subsequent buoyancy changes. Throughout basic scuba diving training most instructors emphasize relaxation and minimum energy expenditure in "normal" scuba-diving. Minimum energy expenditure means (1) lower air consumption, thus extended dive time; (2) less fatigue; (3) more pleasure and relaxation; (4) an energy reserve in the event of an emergency; and (5) in general, safer diving.

The diving industry has met the challenge of developing equipment for buoyancy compensation and flotation purposes. A review of diving equipment catalogs in 1974 revealed more than 40 models of buoyancy vests, buoyancy compensator vests, and backpack mounted buoyancy units. McKenny (1975) describes variable-volume suits currently available to the diving public. Although the 1975 Skin Diver Magazine Reader Survey shows that 65% of the public own scuba safety vests and only 35% own buoyancy compensator vests, I feel the trend is toward the buoyancy compensator. The American diver is, in my opinion, truly becoming a "buoyancy compensation diver."

In this paper I am addressing myself to the philosophy of buoyancy compensation diving rather than a detailed discussion of specific buoyancy compensators. The reader is referred to McKenny (1974, 1975), Fead (1972a, 1972b, 1974) and Tzimoulis (1971, 1972). Probably one of the most interesting papers on the principles of buoyancy control was published by Dickens (1973).

How much buoyancy compensation capability does a scuba diver actually need? There are many variables including type of wet suit, type of scuba cylinders, air volume usage, diving depth, diver breathing characteristics, type of activity, displacement volume and weight of accessory equipment, weight belt, etc. Let us make the following assumptions regarding one type of sport diver:

1. The diver is wearing a standard size large 1/4 in. (6.35 mm) foam neoprene wet type suit.
2. The diver is dressed in full gear and an *empty* scuba cylinder is weighted to be neutral at the surface.
3. The NTP air volume in his cylinder is 71.2 ft^3 (2.2 m^3) when fully charged.

If the diver descends to a depth of 120 ft., wet suit compression will result in a buoyancy reduction of approximately 11.5 lbs (5 kg) (Dey, 1965). In other words the diver is now 11.5 lbs (5 kg) negative-buoyant. Now take into account that the diver, previously weighted for an empty cylinder, has about 5.8 lbs (2.6 kg) of additional weight (the weight of air). He now has a negative buoyancy factor of about 16 lbs. (7.2 kg). A buoyancy compensation capability of at least that amount is required to achieve neutral buoyancy at depth.

The U.S. Navy considers another factor in buoyancy compensation selection or buoyancy criteria. Cetta (1973) discusses the test of 7 buoyancy vests. One of the primary considerations was the fact of "providing enough buoyancy at 130 ft. (39 m) to be considered acceptable as emergency buoyancy devices." This infers that the vest will be capable of bringing a diver to the surface in a positive buoyancy emergency ascent mode. Units with 11 lbs (5 kg) or more buoyancy at 130 ft (39 m) were considered acceptable. The smallest vest indicated in this test series provided 25 lbs (11.3 kg) buoyancy at the surface; I can only assume that this meets Navy criteria since three of the vests are Navy specification vests.

Finally, since some sport divers do use twin 80 ft^3 (2.4 m^3) scuba, a weight change of about 12 pounds (5.4 kg) might be experienced during a dive. Combine this with wet suit compression at 120 ft (36 m) and we have a buoyancy factor of 23.5 lbs (10.6 kg).

Now let's examine another type of sport diver. This diver wears a 3/16-in. (4.8 mm) foamed neoprene wet suit (size large) and dives to only 60 ft (18 m). Based on Day (1965) we determine that he experiences a wet suit compression factor of only 7 lbs (3.2 kg). Also, this diver prefers to be slightly positive at the end of his dive. -Consequently, he weights himself neutral at the surface with a full scuba cylinder. Thus he will have about 5 lbs (2.3 kg) positive buoyancy on the surface at the end of a dive. In this case he will slow his ascent (near the surface) by holding onto a line, flaring out at 10 to 15 ft, or by a reverse sculling motion with the hands. This sport diver has only a 7 lbs (3.2 kg) buoyancy compensation requirement.

McKenny (1974) reports on 10 selected buoyancy compensators. The lift or buoyancy capacity of these units ranged from 19 to 53 lbs (8.6 to 23.9 kg); average 37.5 lbs (16.9 kg). The prices ranged from \$58.95 to \$165.00; average price \$116.1.4. The price will vary with accessories and economic inflation. Two of the backpack mounted buoyancy compensators provide 48 and 60 lbs (21.6 and 27 kg) buoyancy, respectively. McKenny indicates that the small vest with only 19 lbs (816 kg) of flotation capacity "provides only marginal flotation with my face just barely out of the water while simulating unconsciousness." He was wearing standard wet suit and single cylinder scuba, but was weighted "a little heavy" during the test.

THE BUOYANCY COMPENSATION DIVING PHILOSOPHY

The desirability of buoyancy compensation capability, when needed, has been previously discussed. McKenny (1974) elaborates on the use of the buoyancy compensator for (1) buoyancy control at depth, (2) surface use, (3) emergency breathing system, and (4) buoyancy ascent. To many the buoyancy compensator has become the "end" rather than a "means to an end." I'm greatly concerned about the emerging "buoyancy compensator diving philosophy" that appears to dominate certain factions of the diving community. The following are some of my major areas of concern.

First, the manufacturers of buoyancy compensators appear to be in a greatest lift capacity race. The Bouee Fenzy, one of the first true buoyancy compensators introduced into this country had a 30 lb (13.5 kg) capacity. Now the U.S. Divers BC has a 53 lbs (23.9 kg) capacity and the At-Pac approximately 60 lbs (27 kg). Does the diver need this tremendous lift and flotation capability? In my opinion a properly designed unit with 25 to 30 lbs (11.3 to 13.5 kg) of flotation capability is sufficient for the average sport diver.

This increased emphasis on lift capacity has also increased the physical dimensions of the buoyancy vest. Many are bulky and cumbersome; even more disturbing is the increase in length. Many buoyancy vests cover the diver's scuba harness and weight belt release buckles. In some cases, especially on shorter divers, it is necessary to buckle the scuba harness under the vest. This complicates rescue and equipment handling procedures.

The size of most buoyancy compensators makes them undesirable for skin diving. Therefore, the complete diver must theoretically own two vests now.

Second, design criteria modifications have evolved from the increase in buoyancy compensation use. The design criteria in neck configuration and inflation mechanism have shifted in emphasis from lifesaving to underwater buoyancy compensation. Vests which fit closer to the head and those with larger diameter collars around the back of the neck, tend to keep the face higher up into the air. Thus such units, in my opinion, better serve the diver on the surface and in rescue situations. Buoyancy compensator design considerations lead to a reduced collar size with more flotation at chest level one buoyancy compensator has -eliminated the collar, and thus in my opinion, the lifesaving potential of the unit.

Most vest manufacturers have converted to mechanical inflation from the scuba cylinder via a hose from the first stage regulator assembly. This has simplified buoyancy compensation procedures considerably. Most consider this as much safer than "oral" inflation. Other factors of mechanical inflation must be considered:

1. Increased cost of an already expensive item of equipment.
2. Addition of another hose to the regulator and, essentially, another potential air loss location in event of hose rupture or mechanism malfunction.
3. Addition of another mechanical mechanism for potential failure (I should note that a pulmonary barotrauma victim was recently admitted at the University of Michigan Medical Center as a result of uncontrolled ascent when his mechanical inflator malfunctioned and free flowed air into his buoyancy compensator).
4. Some vests are manufactured without self-contained inflation capability. This makes the vest very undesirable for use in skin diving. In theory, the diver must own two vests.

Third, probably the most serious implications of the buoyancy compensator diving philosophy is that it is encouraging weak swimmers to enter the sport of diving. Granted, using surface flotation "elevator-type" BC descents and ascents, an individual may participate in diving with little or no swimming ability. But, what happens what that flotation doesn't work? What happens when the diver is on the bottom, out of air? How does he inflate his BC to ride to the surface? I regret to say that I have seen certified scuba divers who couldn't swim a distance of 50 yards (45 m) without the aid of their flotation equipment.

Fourth, of equal concern, I feel that a number of physically unfit individuals are entering diving each day. Buoyancy compensation diving can and should be easy diving. However, has it encouraged a rather biased attitude toward physical fitness and the diver? A person no longer needs to be fit! What happens. when this person's buoyancy equipment fails or because of tremendous overconfidence, he attempts to dive without the aid of that equipment?

Fifth, many instructors and some manufacturers advocate the use of the buoyancy compensator as a lifting or salvage aid. Using the BC, a diver can recover objects weighing 30 lbs (13.5 kg) or more from the bottom. He simply picks up the object, inflates the BC and floats to the surface. Great, we now have a "human lift bag!" I contend that this is an extremely hazardous and unnecessary practice. I discourage teaching this application of the buoyancy compensator without reservation. The BC is a part of the diver's life-support system. In addition, it is an item of rescue and safety equipment. Besides, several manufacturers produce small lift bags for this purpose. Don't abuse your safety and life-support equipment.

Sixth, let us now explore some of the more recent developments in emergency ascent methodology. Over the past few years there have been tremendous developments in the area of buoyancy compensation equipment. This has added a new dimension to the emergency ascent. Although documented references to positive buoyant ascent training in the sport diving community with ' specific methodology appear to be limited, if not virtually nonexistent, I am aware of such practices. I have observed divers accelerating toward the surface with fully inflated buoyancy units in open water classes being conducted at a northern Ohio quarry. These ascents were initiated in depths of approximately 40 to 50 ft. (12 to 15 m). Similar reports came from other parts of the country. The precedent for this type of ascent has been well established in Navy training under strictly controlled and specified conditions but has only quite recently emerged to specific open water practice levels in the American sport diving community. I must point out that instructions for positive buoyancy ascents are given to British divers in *The British Sub Aqua Club Diving Manual* (Zanellil 1972). However, specific endorsement of the positive buoyancy emergency ascent in routine training at the current time by the British is unclear. It may well be that positive buoyancy ascent procedures utilizing buoyancy units are about to emerge as a "routine" procedure in the American diving community. I caution the divers and the diving instructors regarding this type of emergency ascent. Do not advocate or require open water practice. This ascent may be taught in theory and it may be practiced from a skin diving mode, i.e., descend to 20 or 30 ft (6.3 to 9 m) without breathing from scuba and activate the buoyancy compensator to carry you back to the surface. But stress that actual use from a scuba diving mode is only to resolve a life and death situation.

The increased emphasis on buoyancy compensation diving has also influenced the buddy breathing emergency ascent methodology. With the increased emphasis on buoyancy compensation equipment there appears to be a lesser emphasis on "proper weighting of divers." Although the observations are subjective and the conclusions drawn lack strict scientific basis, I suggest that more than 40 percent of the divers I observed at one northern quarry on several occasions were, in fact, over-weighted. Consequently, in my opinion, excessive compensation was required to offset negative buoyancy at depth. This air must be vented from the compensator in order to maintain an acceptable rate of ascent. In the event of an emergency ascent using buddy breathing techniques, each diver must cope with the added complication of excessive expanding air and manually venting the buoyancy compensator. The positive buoyancy assist might be considered a benefit by some and detriment by others.

The complexity of methodology is further illustrated by the discussion of an emergency buddy breathing ascent procedure recommended in a recently released sport diving manual (Jeppesen Sanderson, Inc., 1975). The following description is quoted from text: "The donor holds the regulator in the right hand and holds the vest inflator in the left hand. The needer grabs onto the donor's right hand and regulator, and holds the vest with the left hand. One buddy inhales from the regulator two times, while the other exhales slowly into the vest inflator. The buddy team continues this procedure until both vests are adequately inflated."

I believe it has already been established that buddy breathing is difficult, if not virtually impossible, under many real (not simulated) conditions. These added inflation procedures only complicate an already marginal procedure. At this point I will pursue buddy breathing methodology further. Graver (1972) and numerous texts elaborate on the procedure.

Finally, the increased use of buoyancy compensation equipment has led to improper weighting of divers. Based on observations at northern quarry locations, I estimate that at least 40% of the divers entering the water are over-weighted by 5 to 15 lbs (2.3 to 7 kg). This, of course, leads to a necessity for buoyancy compensation. Many instructors do not teach weight adjustment or how to select the proper amount of weight.

Over the past two years myself and some Michigan students have been experimenting with non-buoyancy compensation diving (techniques used prior to development of modern equipment). Through proper selection of weight on our belts and relaxed breathing, we have not had to use the buoyancy compensator for routine dives in water depths up to 80 ft (24 m). We wear standard single (cylinder) scuba and 3/16 or 1/4-in. (4. 8 or 6. 35 mm) suits.

CONCLUSION

Divers, instructors, and manufacturers are misusing a desirable and safe diver aid: the buoyancy compensator. This abuse of the buoyancy compensation concept has led to the development of unsafe diving practices. I call upon the diving community to consider the following:

1. Be certain that all applicants for diver training are satisfactory swimmers and physically fit. Do not use the buoyancy compensator as a substitute for swimming ability and physical fitness.
2. Do not use the buoyancy compensator as a lifting or salvage aid. This is abuse of a piece of life-support and lifesaving equipment.
3. Inform your students that the positive buoyancy emergency ascent is to "be used as a last resort to resolve a life or death situation." Do not advocate or require practice of positive buoyancy emergency ascents.
4. Manufacturers are encouraged to re-evaluate the size, design configuration, and materials in vests. Vest must be designed so as not to obscure weight belt and scuba harness buckles. The vest design must be such that it facilitates lifesaving as well as buoyancy

compensation. The trend towards small collars is less desirable for lifesaving purposes.

5. Do not teach the over-use of buoyancy compensation. Correct weight belt buoyancy adjustment is still a vital part of diver training.

REFERENCES

Cetta, T., "New Life Jacks Tested," Faceplate 4(l): 8(1973).

Dey, L., "Know Your Buoyancy," *Skin Diver* 14(4): 40 (1965).

Dickens, R., "Body Position and Buoyancy Control," pp. 71-92 in Mount, T., (ed.), *Safe Cave Diving* (Miami: The National Cave Diving Association, 1973).

Fead, L. "The Truth About Mae West," *Skin Diver* 21(5): 62-63 (1972a).

Fead, L., "Revolutionary Flotation Device," *Skin Diver* 21(6):64-65, 84 (1972b).

Fead, L., "A Second Look at the At-Pac," *Skin Diver* 23(6): 94-96 (1974).

McKenny, J., "Buoyancy Compensator Roundup," *Skin Diver* 23(5): 68-73 (1974).

McKenny, J., "Inflatable Dry Suits," *Skin Diver* 24(10): 26-31 (1975).

Tzimoulis, P., "Nemrod Compressed Air Vest," *Skin Diver* 20(9): 46-47 (1971).

Tzimoulis, P., "Fenzy 70," *Skin Diver* 21(l): 86-87 (1972).