THE CASE FOR A DEVICE TO MANAGE FREEDIVER BLACKOUT

By Dr. Terry Maas

Freediver Brian Yoshikawa mimics shallow water blackout.

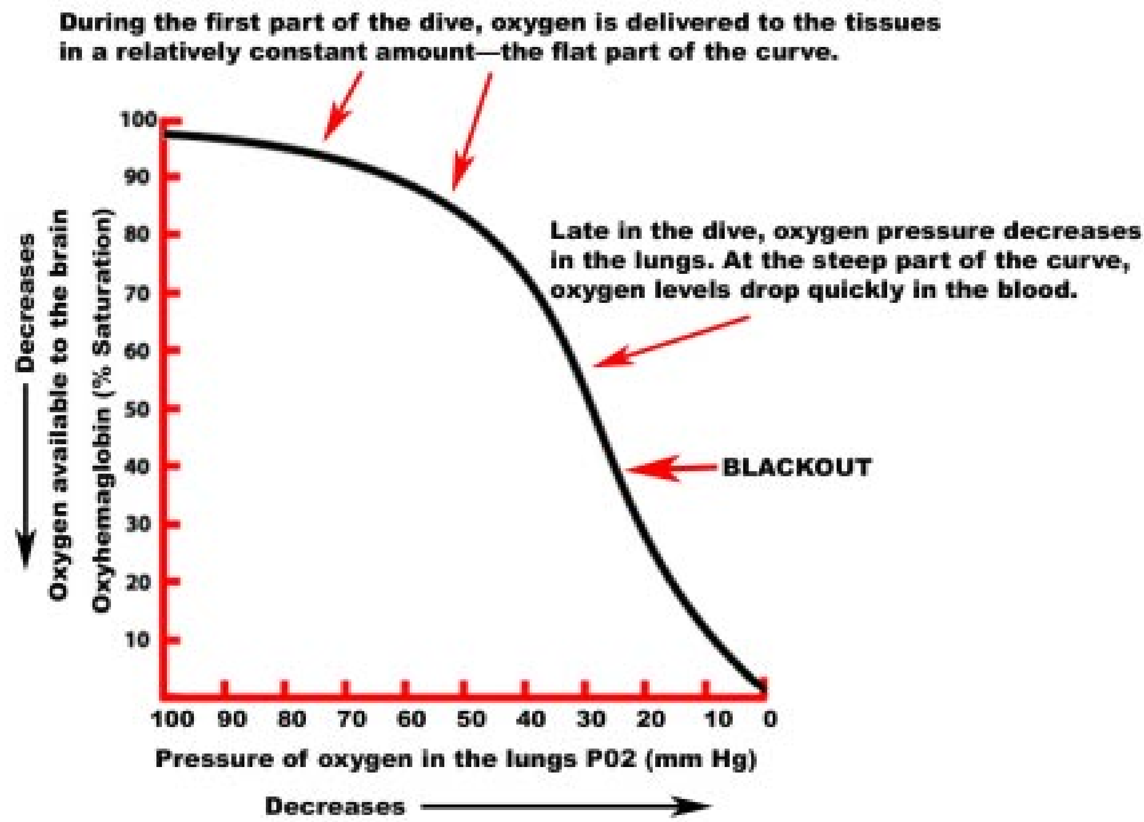
THE PROBLEM:

Well-trained freedivers who know the risks of shallow water blackout (SWB) die at an alarming and predictable rate. The vast majority of SWB victims are found on the bottom with their weight belt firmly in place. Why is this? A recent poll of divers who know their country's statistics reveal that there are more freedivers than we previously appreciated and more deaths from SWB as well. Below is a table with the preliminary poll. As the table developed, a trend emerged. Those who dive in deep, clearer waters are more apt to experience death from SWB.

COUNTRY	FREEDIVERS	SWB DEATHS/YEAR
United States- Continental	10,000	3
United States- Hawaii	5,000	6
Greece	50,000	6
Australia	15,000	10
Italy	12,500	12
Portugal	3,000	3-5
New Zealand	1,000	2
South Africa	8,500	0-1
France	30,000	8-10 (In 2003, 33 French freedivers died from SWB)

There are multiple causes of SWB. Trained freedivers become good at ignoring their desire to breath, can become very focused on a task or can be reluctant to ruin a day's diving by ditching their weight belt. Having survived thousands of freedives, some become over-confident. There is a factor, or combination of factors, working time and again to cause a diver, who did not intend this freedive to be his last, to perish. We know that human physiology changes day-by-day and minute-by-minute. What the diver has grown accustomed to as normal, may be simply beyond his ability to survive in certain instances. In some cases, blackout occurs without warning. In other cases, the severely hypoxic diver is incapable of manipulating his weightbelt quick-release. As the diver approaches the end of his dive, we believe that there is a profound change in his psychology—the diver simply cannot rely on his "internal clock", or whatever mechanism tells him it is time to ascend. Why else would well-trained, physically fit and experienced divers die at such a regular rate with their weightbelts still in place?

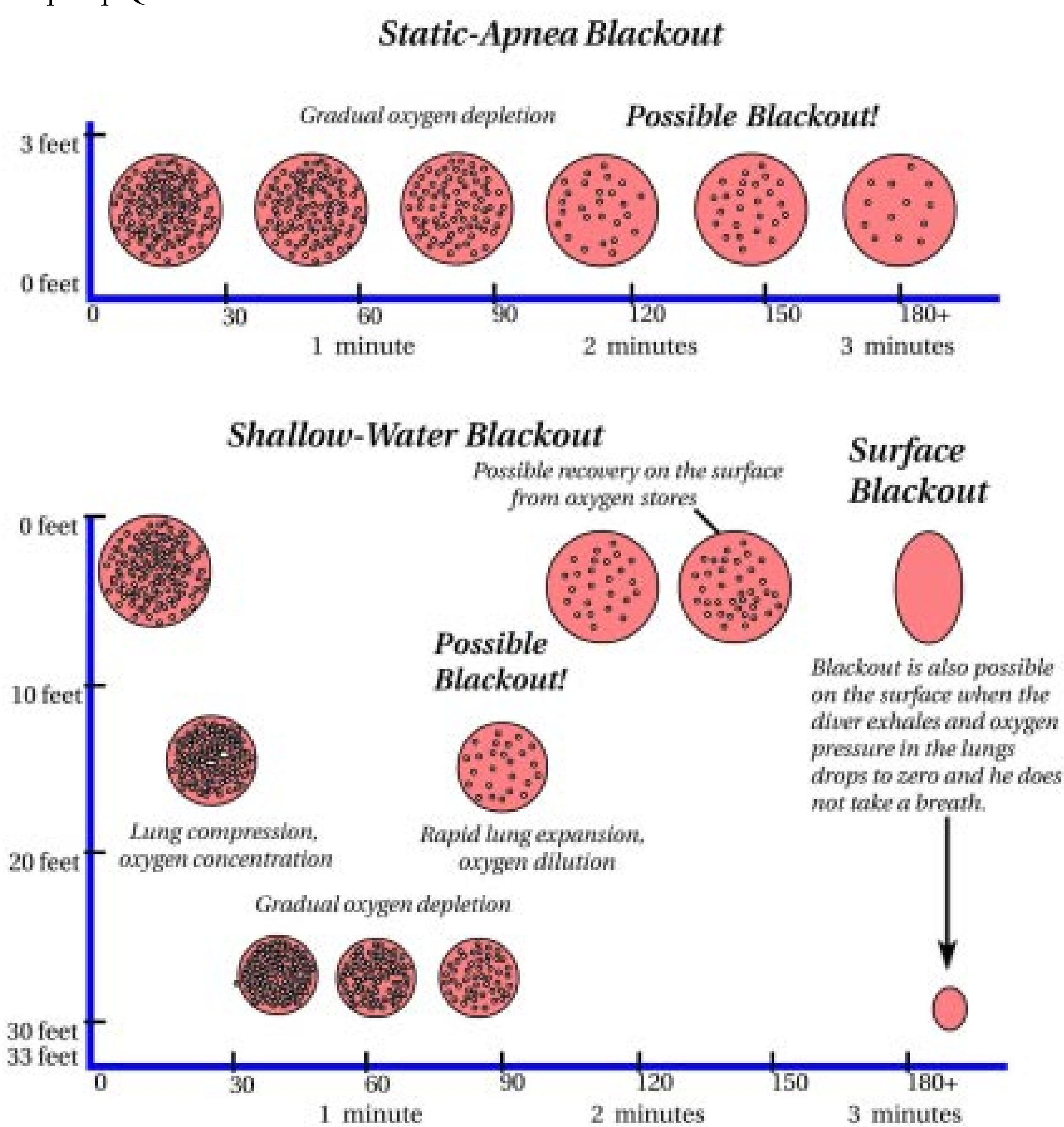
Freedivers blackout when the oxygen content in their brains drops below the level necessary to support consciousness. The brain is more sensitive to the lack of oxygen than other tissues. Furthermore, the way that blood retains oxygen favors a steady metering out of oxygen to the tissues (the flat part of the oxygen dissociation curve—see diagram) during the first part of the dive. As a long breath hold-dive progresses, oxygen levels drop in the lungs, these levels drop even more sharply in the tissues (the steep part of the oxygen dissociation curve.) Rapidly decreasing levels of oxygen available to the brain sneak up on victims with such rapidity that many survivors of SWB do not recall air hunger or impending blackout.



The Oxygen Dissociation Curve

Based on personal interviews, I have classified freediver blackout into 3 groups depending upon during which part of the dive they occur. STATIC APNEA BLACKOUT: Here the freediver dives to the bottom of a pool or body of water and blacks out without ever attempting to return to the surface, or they may even be resting on the surface of the water in face down position. These divers blacked out from lack of oxygen without some of the pressure-compounding problems ascending divers experience. SHALLOW WATER BLACKOUT: SWB occurs when the ascending diver's blood-oxygen levels are low and when the expanding lungs, instead of forcing oxygen into the blood as they do during descent, expand and draw precious oxygen back from the blood. Blackout often happens before reaching the surface. Many of these divers lose control of their breath-hold ability and observers have seen air leaking from their mouths. Unless the diver is very buoyant near the surface, the effects of air compression on the lungs and wet suit combined with the loss of air from the mouth, all increase the diver's tendency to sink back down to depth.

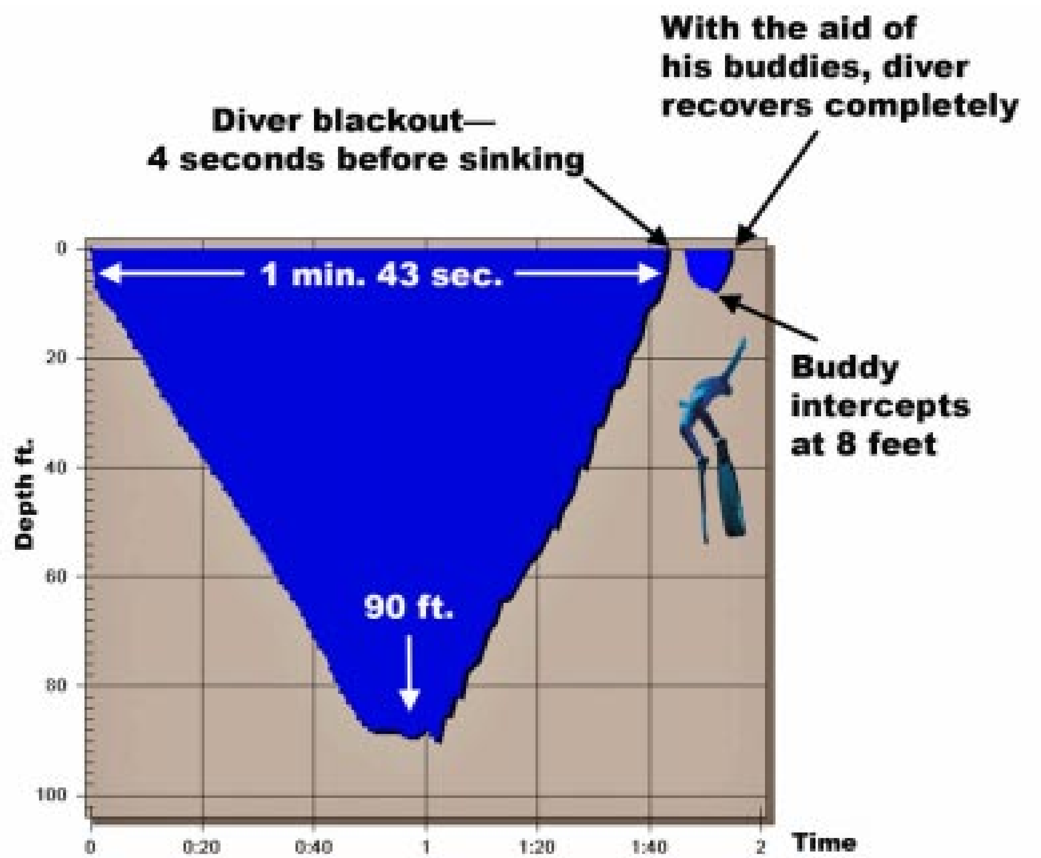
The last and most insidious form of blackout, I'll call SURFACE BLACKOUT: As the distressed diver ascends, the lungs expand, which in turn drops the oxygen pressure and actually draw oxygen from the blood—the vacuum effect. However, as long as the diver holds his breath, there is SOME oxygen pressure available to his blood. On the surface, the diver exhales. Almost instantly, what little oxygen pressure is left in the lungs disappears and the pressure within the chest decreases as well. Exhalation at the surface places the severely oxygen-depleted freediver in potential jeopardy for two reasons: decrease in oxygen pressure in the lungs and decrease in the overall pressure within the chest. For an excellent example of a surface blackout, see this You Tube submission: http://www.youtube.com/watch?v=YXopsexpiQA



1. Oxygen pressure drops: This sudden drop in oxygen pressure in the lungs can precipitate instant blackout at the diver's most vulnerable surface period—before he has taken a breath. When the diver passes out on the surface and has taken in little or no air, he may be negatively buoyant and begin to sink. The water pressure from sinking just a few inches pushes out what little remaining air is in his body and he now sinks like a rock. We have actually witnessed this phenomenon in one individual and confirmed a similar scenario from a another victim's dive computer downloaded profile—each diver ascended gradually, reached the surface for several seconds and then sunk rapidly.

2. Thoracic pressure drops: At exhalation and early inhalation, preload to the heart may decrease and consequently, blood flow to the brain is further compromised—yet another reason for surface blackout.

We also hypothesize that oxygen deprivation (hypoxia) leads to irrational and distorted thinking—most acute in the last 30 seconds of the dive. Why else are victims of SWB routinely found on the bottom with their weight belts firmly in place—their one last potentially life saving effort ignored? Surely, if asked prior to the dive, they would have told us that they would ditch their belts in an emergency. Interviews with SWB survivors reveal that at the end of a long or strenuous dive, divers tend to focus on a goal or on a single thought to the exclusion of more safety-oriented thinking. Their last thoughts are, "Just one more tug and I'll get the anchor free", "I can't let go of my gun or I'll lose it and the fish", or "I'm almost at the surface—I've got it made."



Profile from a diver who passed out after making a 1 min.-43 sec. dive to 90-ft. He blacked out after just 4 seconds on the surface and was quickly rescued by his buddies.

The previous discussion on the causes and physiology of SWB only scratches the surface. The dynamics of the influential gas, carbon dioxide (co2)—the gas you breathe out—is both fascinating and complex. Carbon dioxide levels have profound effects on the diver's ability to hold his breath. Blowing off carbon dioxide by hyperventilating reduces blood co2 levels and can shut off the desire to breathe well past the exhaustion of oxygen supplies in the body. On the other hand, muscular exertion increases blood co2 levels. Changes in carbon dioxide levels can be as important as oxygen levels—it can change the way blood holds oxygen and has a direct effect on your ability to think. Retained carbon dioxide, built up over successive dives, can have an astounding affect on your physiology. High enough levels of carbon dioxide can impair a diver's judgment and may even cause blackout itself. Human physiology changes day-to-day and hour-to-hour. It is influenced by many factors such as rest, fitness, alcohol consumption, drugs, and current mental state. After thousands of successful freedives, we become complacent. Each freedive, culminating on a safe return to the surface, has to be executed perfectly. We are simply not capable of such perfection. Statistically speaking, and in the face of all of the confounding variables mentioned above, it's a wonder we do as well as we do. (For a more complete description of diver physiology and SWB, see *FREEDIVE! By Terry Maas and David Sipperly.)*

Almost any popular sport with such a clear and present danger has adopted safety equipment to mitigate loss of life and limb. Parachutists use a backup parachute, cyclists use helmets and drivers use seat belts, air bags and shoulder harnesses. It's time we protected ourselves from the devastating consequences of SWB. While no device will prevent SWB, we now have the capability to develop equipment to help decrease the incidences of death due to SWB. We are not saying that any device should supplant such freediving safety basics as good training, fitness, caution and an ever-present buddy diver. However, even a buddy cannot guarantee complete safety. If the water

The vest is streamlined and "slippery"

visibility is not clear, it may be impossible for the buddy to follow the progress of the dive. Distressed freedivers can sink so fast that unless the buddy is directly over them, they might sink beyond help. Remember, a buddy capable of diving to 60 feet may become limited to 30 feet when faced with the adrenalin-induced excitement of an emergency and an inadequate pre-dive preparation.

The idea of a safety vest for freedivers is not new. In Europe, where there are more freedivers and clearer water, there are many deaths resulting from SWB. One father of a SWB victim invented a clever hydraulic timing device to activate a carbon dioxide cylinder to inflate the vest. Another suggested a deadman switch, which activates the vest if the freediver passes out and subsequently releases the switch. One major European diving gear manufacturer came close to bringing such a protective vest to market. In April of 2005, over 50 divers collaborated in an Internet-based effort to develop a timed safety vest built from over-the-counter supplies. The most important outcome of this effort was the development of the logic behind the basic functions of the vest. The project had reached a point where someone had to step forward and bring the product to market – thereby making the freediver safety vest a reality.

THE SOLUTION:

Two California freedivers, Jason Bush and Chip Bissell, have teamed up to form *Applied Ocean Specialties, Inc.*, a company dedicated to the research and manufacture of a freediver protective vest. In its simplest form, the freediver, using his wrist display, sets the maximum depth and maximum duration for his dive, which will then communicate these parameters to the back-mounted inflation unit. Normally, these settings will be outside of the diver's normal dive profile so that if the freediver finds himself too deep or has overstayed his time, the vest will automatically inflate and he will be immediately transported to the surface, face-up. ***For an update and the latest advances see: http://oceanicss.com***

To protect the diver in these most adverse scenarios, a computer chip is programmed to use a timer and input from depth sensors. The most common function of the programmed timer will be to fire the vest if the diver stays down too long. Say you are a 2-minute freediver, and you know that if you are still under the water at 2-and-a-half minutes, you are in serious trouble. If you set the timer to inflate at 2-and-a-half minutes, when that time is reached, the vest will fire. Sometimes freedivers hunt in deep water over wrecks or for blue water fish. It is possible for the diver to find himself very deep, sinking fast and in trouble well before the maximum time limit fires the vest. In order to guard against this scenario, and as an additional safety feature, the diver programs the unit to inflate when he exceeds his maximum selected depth. The vest is designed to function to a maximum depth of 120 feet.

To disarm the vest, the freediver swipes his arm unit over a magnet on the vest. To prevent early de-activation of the vest, the timer will not accept the de-activation signal until the diver has successfully reached the surface. We anticipate many divers, who have not passed out, will nonetheless reach the surface confused and in a near black out state—the so called "samba" condition. When they "forget" to deactivate the vest, it will fire. While this might provoke an initial reaction of irritation to some because of the inconvenience of having to refill the vest, it should be obvious how close to total blackout they came. If a freediver experiences many "nuisance" firings, it is hoped that the realization of how close they came to a blackout causes them to change their unsafe diving behavior.

The inflated vest supports the diver face up, out of the water.

We also anticipate that some divers will reach the surface, deactivate the vest and then pass out while exhaling. If this occurs, the improperly weighted diver will sink like a rock. To protect the diver from this situation, we have programmed the vest to fire should the diver descend again to a depth greater than 10 feet during the first 30 seconds after reaching the surface and deactivating the vest. The vest allows a diver to descent to 10 feet in case he needs to dodge an oncoming boat.

The gas powering of the vest will come from a small compressed air bottle, smaller than a soda can. It will be capable of filling the vest in depths up to 120 feet. The cylinder is refillable with a yoke attached to a standard scuba tank or at any dive shop. In the case of an inadequately filled air bottle, the display will warn the diver that the depth he has set is outside the capacity of the bottle to fill the vest. Should the diver attempt to dive, the vest will immediately fire, preventing him from using the vest with an inadequately filled air source.

The wrist unit, actuator and vest will be made from high quality materials with aircraft-type redundancy built into critical elements such as the solenoids that open the air source. The user can easily charge the battery. A test mode will allow the user to check out the equipment before he enters the water. The actuator components will be built in a streamlined fashion to fit just above the weightbelt in the small of the back.

The vest should never be used as a replacement for good freediving practices, which include the use of a buddy, proper surface intervals, proper weighting, adequate preparation before each dive, rest, fitness and simple common sense. The vest is not be used in any overhead environments or in areas with heavy boat traffic, nor can it be used in shallow depths such as the surf zone or a swimming pool. Too many freedivers have lost their lives needlessly. It's time to use technology to our advantage. Used correctly, this device may help many of our freediving brothers across the world survive our biggest enemy….SWB. The freedivers' safety vest – IT'S ABOUT TIME!

Acknowledgments: The author would like to thank the original Internet collaboration team that developed the basic theories for the vest's operation. I would also like to thank to the safety vest development team of Jason Bush and Chip Bissell, Sheri Daye and David Sipperly. Special thanks to co-inventors Sheri Daye and David Sipperly for their invaluable ideas, for their enthusiasm for this project, and for their critical editing of this piece.

About the author: Four-time national champion and world record holder, Dr. Terry Maas is also an oral surgeon. Trained in anesthesiology at the University of Southern California, Maas studied respiratory and cardio-pulmonary physiology and administered over 20,000 general anesthetics.

Disclosure—financial interest: The author presented this paper at the Breath-Hold Diving workshop in 2006. At that time he had no economic connection to *Applied Ocean Specialties, Inc.*, the original development entity extant when this report was submitted to the symposium at Orlando, Florida in June 2006. In early 2007, *Oceanic Safety Systems LLC*, purchased all the assets of the original corporation in order to develop a prototype Freediver's Recovery Vest. Terry Maas does now have a financial interest in the new entity. ***For an update and the latest advances see: http://oceanicss.com***