What happened to Sheck Exley?

by Bill Hamilton, Gordon Daughtery, Ann Kristovich, and Jim Bowden.

Excerpted with permission from the Undersea Hyperbaric Medical Society's newsletter, "Pressure."

On 6April94, cave diver and explorer Sheck Exley died attempting to reach the bottom of the Zacatón sink hole in northeastern Mexico. This physiological analysis relates the conditions and events of the dive as well as we can reconstruct them, and speculates on possible causes of his death. It is not intended to endorse or glorify record-setting exploration nor to judge it in any way; that stands on its own merits as the prerogative of the explorers. These are the facts of the case as well as we can put them together, plus some speculation.

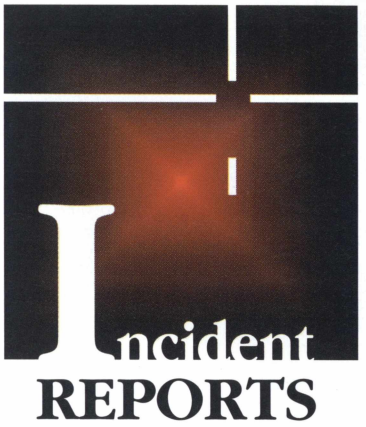
Exley, 45, died while exploring a sink hole or cenote, at Zacaton, located in northeastern Mexico, not far from Mante, the site of his previous record dives. At a depth of 1080f/332m or more, Zacaton may be the deepest water filled pit in the world. Exley was diving with Jim Bowden as part of Bowden's "El Proyecto de Buceo Profundo" project. On the day of the fatal dive, Bowden and Exley dived independently, but at the same time and with similar techniques.

Bowden and Exley descended on separate weighted guidelines 25 to 30 feet apart. Bowden started a few seconds before Exley; the descent was expected to take 10 to 12 minutes. The divers kept track of the line visually. From a decompression and gas management point of view, the more rapid the descent the better, but a rapid descent potentially may exacerbate the effect of High Pressure Nervous Syndrome (HPNS) (See aquaCorps Journal N8, "High pressure nervous Syndrome," by R. W. Bill Hamilton). Both divers had experienced HPNS symptoms on previous dives and planned to slow their descents to less than about 100 f/min (30 m/min.) at about 680 f/229 m. Air was breathed by both divers to 290 f/92 m at which point Exley paused to "stage" his air cylinder by clipping it to the line at 290 f. Bowden used a small "pony" cylinder carried on his back as his air supply. The divers switched to a "travel" mix, trimix 10.5/50 (10.5% O2, 50% He, bal. N2), for the descent from 290 to 580/89-179 m .

Both Bowden and Exley selected a bottom mix that would produce a tolerable PO_2 of less than 2.0 atm and an equivalent narcosis depth (END, the equivalent depth on air) of 274 f/84 m at 970 f/298 m. These levels were accepted by both divers since the exposure to maximum depth would be brief (*Note that a higher PO2 would minimize the lengthy decompression at the cost of increasing the risk of CNS oxygen toxicity. Technical divers are recommended to run their working PO2s at less than 1.4 atm. See aquaCorps N7, "Blueprint For Survival Revisited"—ed.*). Bowden used trimix 6.4/31 and Exley used trimix 6/29 (mixed by adding helium to air). Both divers used gas from the back mounted bottom mix supply to fill their buoyancy compensators (BCs).

Sheck carried a total of about 369 cf (standard cubic feet) of bottom mix in two large back mounted tanks. He also had two side mounted tanks (aluminum "80s" filled to 3600 psi) of trimix 10.5/50. Jim carried 426 cf of trimix 6.4/31 in two back mounted tanks and in one side mounted aluminum "80" tank. A second side mounted "80" tank contained trimix 10.5/50. Tanks filled with specific decompression mixtures had been staged on each individual's descent line during the two days prior to the dive. The extended decompression called for mixes of air, enriched air nitrox, argon-oxygen, and oxygen.

It is difficult to overemphasize the importance of gas management and careful gas planning for a dive of this magnitude. At 30 atmospheres (970 f/298 m) the amount of gas in a normal 72cf scuba tank is reduced to less than 2.5 effective cubic feet—good for 2 or 3 minutes, less if exercising. Bowden and Exley followed a rigorous pattern of breathing, taking slow, deep breaths at a practiced rate in order to optimize the tradeoff between excess gas consumption and hypoventilation—which leads to CO_2 buildup. A small change in the breathing pattern, especially in rate, can quickly alter usage calculations.



Bowden checked his gas volume at about 874 f/268 m. He had expected to have approximately 1800 psi (pounds per sq. in.) at this point and had only 1000. He realized the need to turn the dive and arrested his descent at the 898 f/276 m mark. On the line during decompression, Bowden observed Exley's unused decompression tanks and correctly assumed that Exley had not survived. The support team realized this 18 minutes into the dive when the trail of bubbles on Sheck's line disappeared. Bowden completed his nine plus hours of decompression, surfaced with shoulder pain, and was treated with oxygen, corticosteroids, and hydration.

The postdive analysis does not adequately explain the shortage of gas. In 1993 December, Bowden dove to 776 f/238 m in the same system, confirming his anticipated gas usage, as had previous dives to 722 f/222m and 489 f/150 m. Sheck's gas usage in an earlier dive in Bushmansgat confirmed that his gas management technique was adequate.

Bowden concedes that even a slight elevation in breathing rate, beyond his practiced 5-6 breaths/min, would account for the added gas consumption on this dive. Both divers had planned to slow their descents at 679 f/209 m using their BCs which consumed precious bottom mix. Additionally Exley, who had started the dive with less volume than Bowden, slowed at 291 f/84 m to drop his air tank used in the initial stage of the dive.

The day after the dive, topside team member Kristovich and others returned to recover equipment from both lines. Exley's was heavy with his staged steel tanks, and plans were made to raise the entire line with a pulley assist from the surface. Two days later, during this process, Exley's body surfaced. The line was wrapped several times around both arms and the valves of his side mounted bottles. Entanglement did not involve the back mounted bottles, valves, mounting plate, or BC. His mask and all other equipment was in place. He did not have a regulator in his mouth. His BC contained gas and the inflator was functional. His wrist mounted dive computer revealed a maximum depth of 879 f/270 m. The gauge for his back mounted tanks read 500 psi, the lowest pressure that would effectively supply gas to the diver's regulator at bottom depth. One regulator of his two side mounted tanks was unhooked and the pressure was 500 psi. The second tank had 3600 psi and the regulator was stowed. A later analysis of the gases for the oxygen component revealed accuracy in the expected mixes. An autopsy was ordered but nothing reported explained the accident. Three days passed since the death, and that combined with the effects of immediate decompression made a confident postmortem analysis difficult.

What went wrong?

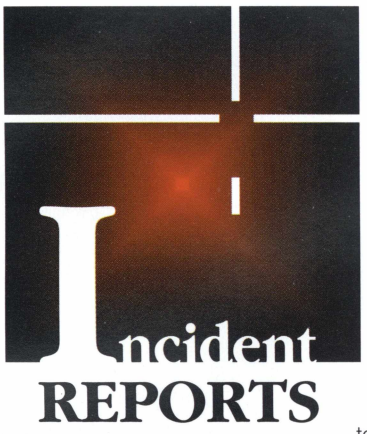
We will never know for sure. Most likely Exley reached a point where he was unable to inflate his BC mechanically with compressed gas and wrapped the line around himself to stabilize himself while sorting things out. His maximum depth was 879 f/270 m. Exley may have ascended 75 feet or more, but that cannot be determined for certain from the recovered line, since it was cut during removal from the water. The manner in which the line was wrapped around his upper body makes it unlikely that the entanglement could have happened accidentally, even if a convulsion had occurred. Exley's experience level makes this unlikely as well.

If we accept this, the main uncertainty is why or how he became so low on gas. It was not like Exley to fail to check his gas supply, but the physiological stress of the rapid compression (HPNS) could have occupied him enough that he was not aware of his situation until it was too late. The equivalent nar-

cotic depth of his mix was approximately 242 f/75 m at a depth of 879 f/270 m, an air depth easily within his comfort level, but also a potential contributor to the probable cascade of problems. The gas density was 14 g/l at this depth, the equivalent of breathing air at 334 f/106 m. Resistance to breathing plus intentional slow breathing undoubtedly resulted in an increased level of CO_2, possibly high enough to impair performance.

Exley had used some of his trimix 10.5/50 travel mix for the descent, but would not have consumed gas down to 500 psi on that portion of the dive. The travel mix could have been lost to free flow, but more likely Exley breathed it when the supply of trimix 6/29 was exhausted. This was a "hot" mix at 879 f/270 m, where the PO_2 would be 2.9 atm; the equivalent narcosis depth was 423 f/130 m, and the gas density 21 g/l, equivalent to breathing air at 487 f/154 m. It could have been breathed during a quick ascent if everything else were under control. However, with the contributory factors of the neurological hyperactivity due to HPNS, his exertion, and an inevitable CO_2 buildup, it is possible that central nervous system (CNS) oxygen toxicity caused incapacitation or a convulsion. A phenomenon known as "deep water blackout" has caused many divers under less stress to lose consciousness without convulsing. Its exact physiological course, including the cause, is not known.

In addition, equipment failure cannot be entirely ruled out. A free flow of the primary regulator at depth would have contributed to a very rapid loss of volume and consequent reduction of vital gas reserves.



Conclusions

The most likely sequence of events was that Exley got behind on his gas management, ran low on bottom gas, and could not control his buoyancy so could not ascend. The cause is not clear, but a combination of factors could include stress of HPNS exacerbated by the narcotic effects of nitrogen and CO_2. He stabilized his position by wrapping his descent line around his arms, was forced to switch to his trimix 10.5/50 at a depth of at least 800f/246m, and was subsequently incapacitated by the prevailing conditions of HPNS, hyperoxia, exertion, CO_2 buildup, and nitrogen narcosis.

The accident could have occurred as a physiological consequence of an illness, known or unknown, that could lead to death or incapacitation on any day in an individual involved in strenuous activity. Likewise mechanical failure, such as something that could cause unexpectedly fast gas consumption or loss, cannot be ruled out.

R.W. Bill Hamilton, Ph.D., is a physiologist and editor of Pressure. C. G. Daugherty, M.D., is a diving doctor specializing in occupational medicine. Ann Kristovich, DDS, is an oral surgeon and diver and medical officer for the Zacatón project. Jim Bowden is a diving instructor at the University of Texas and produced much of the material used in this article.

Bakerston Mine, Harpers Ferry, West Virginia

94JUL— A certified cave diver apparently embolized and died when his DPV trigger stuck in the "on" position dragging him to the ceiling of the cave following a gas switch from trimix to air at a depth of 200f/61m on the return leg of an exploration run. Prior to the switch, the diver had drained his doubles—violating the "thirds rule"—and was forced to share gas with his partner and swim for safety when his reserve cylinder regulator failed to function—the regulator hose being too short to permit scootering.

The team's objective was to explore beyond the the end of the existing permanent line at approximately 1650f/503m at a depth of 285 f/88 m. The team began the dive by motoring in 900f/274m to a depth of 200f/61m where they switched from air to trimix. The dive continued to a landmark known as "The Rock" at a depth of 250 f/78 m at 1200 ft/366 m. At this point the cave sloped to 270 f/83 m over a distance of several hundred feet (61 meters). The diver dropped his DPV due to the limited depth rating of the vehicle and swam as his partner slowly motored along. The end of the line was reached without incident at a depth of 285 f/86 m and the team added another 150 f/46 m of line to a depth of 305 f/94 m. The dive was called and the exit began.

The team returned to the staged DPV at 270 f/83 m at which point the diver attempted to switch to his reserve cylinder, his doubles being empty. Apparently, his regulator would not deliver any gas. Realizing there was a problem, his partner handed the diver a regulator from one of his two trimix stage bottles, however, the short hose made it impossible to motor so the team swam their DPV's back to The Rock. At this point, the diver switched back to his air stage and the team motored approximately 300f/91m up the ledge to the big room at a depth of 200f/61m.

Once they entered the room, his partner felt a DPV blast and saw a flash of light. He turned to find the diver unconscious on the ceiling—the DPV running circles around him. The trigger was stuck "on." There was blood in the diver's mask. He cut away the DPV and tried to hold a regulator in the diver's mouth with no response. The partner then attempted to tow him out but had to leave the diver to complete his own decompression.

The recovery team had no problems locating and extracting the body. All equipment was functioning properly, including all regulators. The doubles were empty and the single 80 with trimix was full with the regulator working properly.

The diver had a reputation for violating the thirds rule, had previously run out of gas on at least three cave dives, and had experienced "deep water blackout" (where a deep air diver is rendered unconscious) at 210 f/65 m while switching from bottom mix to air during a previous dive to the site and survived. An astute dive partner held his regulator in his mouth until he regained consciousness.

Lusitania, Kinsale, Ireland

94AUG—Two months after the Tapson expedition was completed without incident, a 37 year old diver "blew up" to the surface from a 280 f/86 m trimix dive on the Lusitania, incurring severe injuries.

After descending to the wreck, the diver's partner began to lay line from a descent line. The two became separated when the diver's stage cylinder came undone from his harness. He tried unsuccessfully to reattach the cylinder and in the process, became severely entangled in the line. He then dropped a cutting tool that he had intended to use to disentangle himself. His partner returned to assist and cut him free, but the diver apparently panicked and blew up to the surface legs first. He was diving on a trimix 12/26 (12% O2, 26% He, balance N2) and his surface to surface interval was about 12 minutes.

The injured diver was flown to the Naval recompression chamber at Haulbowline near Cork, Ireland. On arrival, the injured diver was weak but moving all limbs with good preservation of cortical function and absolutely no evidence of pulmonary barotrauma. His condition continued to worsen and he was treated with little success.

The diver had been certified for nitrox and trimix diving less than four months before his accident and had been advised by his instructor that his experience level was insufficient to attempt the Lusitania in 1994 without more experience. It is unknown whether the diver, who is now a quadriplegic, will ever walk again.