

## ORIGINAL ARTICLES

### PROVISIONAL REPORT ON DIVING-RELATED FATALITIES DURING 1989

Douglas Walker

#### Summary

There were 19 cases of diving-related deaths identified as having occurred during 1989 in Australian waters. Three of these were associated with breath-hold diving, 13 were scuba divers and three were using compressor-supplied hookah apparatus. This list, like those in all previous years, may be incomplete because of the lack of reporting of "diving incidents" by, and to, the diving organisations, which continues to be a (regrettable) fact.

Two of the breath-hold divers were spear fishing, one dying from a cardiac cause and the other following hyperventilation. The third diver is thought to have lost alertness and then drowned when hit on the head by a "frisky" potato cod. On this case, there is deficient data because, like in several other cases, the local Coroner thought the calling of a formal inquest to be unnecessary.

All three hookah deaths (one a double fatality) were due to carbon monoxide poisoning following positioning of the air intake hose where exhaust fumes from the compressor motor could be entrained.

In the scuba category there were 7 instances where CAGE was either the proved or clinically probable critical factor. Of these two were in relation to aborted buddy-breathing during ascent. Four were persons who had not dived during the preceding 12 months. The majority of fatalities occurred after separation from the dive partner(s) or in a solo diving situation. Where buddies were in a position to assist they performed well. Examination of the records of these cases confirms the importance of regarding the opinions of pathologists, concerning both their findings and their interpretation of the cause of death in diving-related deaths, as needing analysis and not necessarily to be accepted as being beyond legitimate dispute. This is true even in some instances where the pathologist has appeared to follow a "diving death" autopsy protocol.

#### Case reports

##### BH 89/1

Although he had been a keen spear fisherman in his younger days he had given it up for many years because of sinus problems and had only resumed the sport 8 months before the fatal dive. He was on medication for hypertension. Its treatment and severity is unknown but he was known to comply poorly with advice to take his tablets. He

swam out to a reef with his buddy, both spearing several fish before reaching it. The buddy wished to continue around the reef to hunt on the seaward side but the victim said he was thoroughly tired and had cramps in his feet and he was going to return to the beach. When he started his return swim his buddy decided follow suit. During this swim they each speared another fish. The buddy was initially 2 m from him but they became further separated and the buddy reached the beach first. He had looked back from time to time and noted his companion's absence from the surface, naturally (and undoubtedly correctly) assuming that he had dived again. After he reached the beach he became concerned because he was unable to see his friend at the surface so climbed up onto some wreckage to obtain a better view. He saw nothing so swam out and then noticed the victim's spear gun on the sea bed. It had been fired. There was no sign of the victim.

His search being unsuccessful, he gave the alarm, but despite the efforts of searchers the body was not recovered till one week later. The weight belt was still in position. The autopsy revealed that he had an enlarged heart and that both coronary arteries were markedly atherosclerotic, with 50-80% narrowing of their main segments. It was assumed that he had suffered a cardiac problem while making strenuous efforts to shoot a fish, then drowned. There is also the possibility that he suffered a post-hyperventilation blackout, particularly if he had been attempting to show that he had lost none of former skills.

SPEARFISHING. SEPARATION/SOLO AT SURFACE. HYPERTENSION. POOR ADHERANCE TO MEDICAL ADVICE. CORONARY ARTERIES NARROWED. ATHEROSCLEROSIS. NO BUOYANCY VEST. FAILED TO DROP WEIGHT BELT. POSSIBLE POST-HYPERVENTILATION BLACKOUT. FATIGUE. NO INQUEST.

##### BH 89/2

This young man was regarded as a good breath-hold diver but no description of his skill is available. He had recently completed a basic scuba course and was employed on a boat which took tourists to dive on the Barrier Reef, so had opportunities to dive. On this day he was without duties on the boat and was apparently swimming and breath-hold diving near the boat while the passengers were snorkeling or scuba diving at the nearby cod hole. It was not until there was a second query from one of these tourists concerning the length of time he had been underwater that a check was made on the boat and his absence was confirmed. As the divemaster was preparing to enter the water to search for him, one of the returning divers observed the body on the sea bed, in 15 m of water. When the body was raised a bruise was observed over the right eye and although no intra-cranial damage was found at the autopsy the local opinion was that one of the

## PROVISIONAL REPORT ON AUSTRALIAN

Case	Age	Training and Experience		Dive Group	Dive purpose	Depth m (ft)		Weights	
		Victim	Buddy			Dive	Incident	On	kg (lb)
BH89/1	42	Experienced	Experienced	Buddy Separation before incident	Spear fishing	Not stated	Surface	On	4 (9)
BH89/2	24	Trained Experienced	None	Solo	Recreation	12 (40)	Not stated	None	None
BH89/3	26	Trained Experienced	Trained Experienced	Group Separation before incident	Cray fishing	4.5 (15)	Not stated	On	12 (26)
SC89/1	26	Trained Some experience	Experienced	Buddy Present during incident	Recreation	12 (40)	Surface	On	12 (26)
SC89/2	35	Trained Experienced	Trained Inexperienced	Buddy Separation during incident	Recreation	18 (60)	18 (60)	On	11 (24)
SC89/3	48	Trained Some experience	Trained Inexperienced	Buddy Separation during incident	Recreation	15 (50)	15 (50)	On	9.5 (21)
SC89/4	37	No training or experience	None	Solo	Recreation	6 (20)	Surface	Ditched Tangled	21 (47)
SC89/5	51	Trained Experienced	Trained Inexperienced	Buddy Separation before incident	Recreation	18 (60)	Ascent	On	7 (15)
SC89/6	36	Trained Inexperienced	Trained Inexperienced	Group Separation before incident	Recreation	14 (46)	Surface	Not stated	Not stated
SC89/7	48	Trained Experienced	None	Solo	Recreation	12 (40)	Not stated	On	Not stated
SC89/8	50	Trained Experienced	Trained Experienced	Buddy Present during incident	Deep Dive	29 (95)	Ascent	On	Not stated
SC89/9	31	Trained Very experienced	Trained Experienced	Buddy Separation during incident	Deep diving Course	33 (110)	29 (95)	On	12 (26)
SC89/10	30	Trained Some experience	Not stated	Trio Separation before incident	Recreation	9 (30)	Not stated	On	Not stated
SC89/11	46	Not trained or experienced	Trained Experienced	Buddy Separation before incident	Crayfish	Not stated	Surface	On	Not stated

**DIVING-RELATED FATALITIES 1989**

<b>Contents gauge</b>	<b>Bouyancy vest</b>	<b>Remaining air</b>	<b>Equipment Tested</b>	<b>Equipment Owner</b>	<b>Comments</b>
Not applicable	No	Not applicable	Not applicable	Own	Hypertension and fatigue. Coronary artery disease.
Not applicable	No	Not applicable	Not applicable	Own	Possibly hit on head by Potato Cod.
Not applicable	No	Not applicable	Not applicable	Own	Post-ventelation blackout. History of asthma
Yes	Inflated	Low	Significant fault	Borrowed	No dives in the previous 12 months. Leaky mouhtpiece. CAGE.
Yes	Not inflated	Yes	No faults	Own	No dives in the previous 12 months. Vomited. Water aspiration. Possible CAGE
Yes	No	Low	Some adverse	Own	Current. Rough water. Regulator problem. Cardiac insufficiency.
Yes	No	None	Some adverse	Borrowed	First use of scuba. Very experienced with hookah. Contents gauge error.
Yes	No	Low	Some adverse	Hired	No dives in the previous 12 months. CAGE.
Yes	Not stated	Low	Significant fault	Own	No dives in the previous 12 months. Aspiration of vomit. Gauge error.
Yes	Not stated	None	Some adverse	Own	Delay of 14 weeks before equipment was tested.
Yes	Not stated	Yes	No faults	Own	Buddy breathing ascent. Safe error in gauge. CAGE.
Yes	Not inflated	Yes	Significant fault	Own	Buddy breathing ascent failure. Mismatch of equipment. CAGE.
Yes	Not worn	None	Some adverse	Own	Left buoyancy compensator in boat. Epileptic. CAGE.
Yes	Not Inflated	Yes	No faults	Own	Cardiac death ?

## PROVISIONAL REPORT ON AUSTRALIAN

Case	Age	Training and Experience		Dive Group	Dive purpose	Depth m (ft)		Weights	
		Victim	Buddy			Dive	Incident	On	kg (lb)
SC89/12	45	Trained Some experience	Trained Some experience	Buddy Separation before incident	Recreation	12 (40)	Not stated	Ditched	Not stated
SC89/13	42	Not trained Some experience	Not stated	Group Separation before incident	Spearfishing	6 (20)	Not stated	Off Ditched	Not stated
H89/1	16	Scuba trained Inexperienced	Not trained Experienced	Separation	Work	15 (50)	15 (50)	On	Not stated
H89/2	28	Not trained Experienced	Scuba trained Inexperienced	Separation	Work	15 (50)	15 (50)	On	Not stated
H89/3	21	Training not stated Experienced	None	Solo	Work	7.5 (25)	7.5 (25)	On	18 (40)

potato cod had been "too frisky" and had collided with him, rendering him dazed or unconscious and unable therefore to protect himself from drowning. As no inquest was thought to be necessary there are some details not available concerning this case.

SOLO. BREATH-HOLD. DELAY BEFORE ABSENCE NOTED. NO WEIGHT BELT WORN. POSSIBLE HEAD TRAUMA FROM FISH. EXPERIENCED BREATH-HOLD DIVER. NO INQUEST.

**BH 89/3**

Few if any spear fishermen consider it either practical or even necessary to follow buddy diving procedures or have a surface watcher while spear fishing. It is for such reasons that a post-hyperventilation blackout can so readily result in drowning. This victim was not only a competitive minded spear fisher and hunter of crayfish but was also a scuba instructor. This outing was an end-of-season special dive for the instructor staff of a dive shop and the victim had collected several crayfish while scuba diving in company with the others. They had not practiced any buddy diving discipline because, as the skipper said, "They were not paying passengers". He appeared to consider it natural that they failed to practice what they taught others to do.

It had not been intended that they would breath-hold dive but the sea conditions were so unusually calm that it was decided that they could dive on a reef which contained a

wreck, which was close to to their return course. It was only after the others had returned to the dive boat, and had allowed a margin of time for his known determination in the hunt to be fully satisfied, that they became aware of and worried by his absence and started a search. He was found, still wearing his weight belt, lying free on the sea bed in water only 3 m deep. It is probable, but unproven as the belt was lost during the body recovery, that he had been wearing the heavy belt he used while scuba diving. He was reportedly an asthmatic and had been advised for this reason not to continue diving. There is nothing in the history of his diving or of this incident which implicates asthma as a factor. He was reportedly careful to monitor his lung function with a flowmeter before going diving, though such a course cannot protect anyone against bronchial over responsiveness should they inhale a fine spray of sea water during the dive. The circumstances here are typical of a post-hyperventilation blackout followed by drowning. This was mentioned at the Inquest but not noted in the formal findings.

EXPERIENCED BREATH-HOLD DIVER. CRAYFISHING. SEPARATION/SOLO. FAILED TO DROP WEIGHT BELT. NO BUOYANCY VEST. ASTHMA HISTORY. POST-HYPERVENTILATION BLACKOUT.

**SC89/1**

Although the divers had been trained three years ago the buddy had dived frequently since then, while the victim

**DIVING-RELATED FATALITIES 1989**

<b>Contents gauge</b>	<b>Bouyancy vest</b>	<b>Remaining air</b>	<b>Equipment Tested</b>	<b>Owner</b>	<b>Comments</b>
Yes	Inflated stated	Not	Some adverse	Hired	Ditched equipment. CAGE.
Not stated	No	Low	No faults	Own	Rough water. Fatigue. Backpack unbuckled.
Not applicable	No	Not applicable	Significant fault	Employer	Compressor lacked inlet hose. CO poisoning. Delay before being found. Adverse comments on training and work safety practices.
Not applicable	No	Not applicable	Significant fault	Employer	Compressor lacked inlet hose. CO poisoning. Delay before being found. Adverse comments on training and work safety practices.
Not applicable	No	Not applicable	Significant error	Own	Malposition of air intake hose. CO poisoning.

was making his first dive after 12 months without diving. This was a boat dive and also aboard was an instructor with one pupil and a child (who was left on the boat while the others were in the water). The victim and his buddy made an uneventful dive through a narrow cave and emerged after a normal ascent on the other side of the small island. They decided to swim back on the surface around the island using their remaining air, first having exchanged "OK?" signals. After they had been swimming for only a short time the buddy looked back and saw his friend was stationary, so returned to him. He said that he was feeling very tired, so the buddy started to tow him, but shortly after this his eyes rolled up and he lost consciousness.

The buddy managed to pull him up onto a flat rock and was greatly relieved to see the dive boat was coming towards them. The instructor had realised that their dive time was nearly up and had decided to collect them. He swam to the rock and began expired air resuscitation (EAR), first having sent a radio call for assistance. There was no response to his resuscitation efforts.

When the equipment was checked it was noted that there was a fine spray of water with each inhalation, the consequence of a fine hole in the rubber mouthpiece. The autopsy revealed evidence of air embolism, the pre-autopsy X-ray films showing the presence of air in the heart and aorta. It is noteworthy that the ascent was apparently correctly performed and that there was a delay before the onset of symptoms of significance. The inhaled spray may

have altered lung function and been a significant and adverse factor in this fatality.

TRAINED. NO DIVES FOR 12 MONTHS. NORMAL ASCENT. SURFACE DELAY BEFORE ONSET OF FATIGUE SYMPTOMS. VALIANT BUDDY RESPONSE. DELAY BEFORE START OF RESUSCITATION. REGULATOR MOUTHPIECE HOLE CAUSED WATER SPRAY INHALATION. CAGE. AIR EMBOLISM SHOWN BY X-RAY. NO INQUEST.

**SC89/2**

The victim was considered to be an experienced diver but he had not dived during the previous 12 months. He was alert and appeared to be in good health despite having attended a "bucks night" prior to this dive. He was paired with another diver and entered the water first, snorkeling at the surface while waiting. Their descent was slow, as the buddy had some difficulty equalising his ears. The visibility was poor and the buddy was nervous so they maintained close contact with each other, water depth 18 m. After about 5 minutes the victim indicated his wish to ascend and immediately started a rapid ascent without waiting for his buddy to respond. The buddy attempted to keep up with him but was unable to do so despite inflating his buoyancy vest and made a somewhat panicky, rapid ascent, but reached the surface without ill effects. He could not see his companion anywhere and it was only after he had been taken aboard the dive boat that he saw him floating unconscious at the surface.

When reached, it was seen that the inflation hose to his buoyancy vest was not attached. It was found that he had inhaled vomit, and this could very well be what triggered his sudden decision to ascend. Although no pulmonary barotrauma or air embolism was detected at the autopsy it is probable that this occurred during his urgent ascent.

TRAINED. EXPERIENCED. NO DIVES PREVIOUS 12 MONTHS. SUDDEN DECISION TO MAKE RAPID ASCENT. SEPARATION FROM BUDDY RESULTED. UNCONSCIOUS AT THE SURFACE. ASPIRATION OF VOMIT. BUOYANCY VEST INFLATION HOSE NOT CONNECTED. WEIGHT BELT NOT DROPPED. INADEQUATE SURFACE COVER. POSSIBLE CAGE.

### SC89/3

The buddy was just certificated, the victim trained for a year but still very inexperienced. The dive was well conducted by a dive shop and they were making their second dive of the day and had surfaced after an uneventful dive and ascent when the buddy noticed that the victim appeared to be fiddling with his regulator. The sea was now rougher than when their dive had started. The victim did not answer when asked if he was all right, instead pointing towards the dive boat and then starting to swim towards it. The buddy was therefore not alarmed and he began to swim towards the boat, looking towards his companion occasionally but unable to see him because of the waves. In fact the buddy overswam the dive boat for this reason and was therefore surprised when he reached it to find the victim was not already there. It was only then that the victim was seen floating, face down, at the surface about 40 m from the boat. The buddy immediately swam to him and towed him to the boat, attempting to keep his face above the water. He ditched the victim's equipment and attempted to give EAR resuscitation in the water, a task taken over by the instructor, who had just then surfaced with his pupil and observed what was happening.

The autopsy revealed the presence of anatomically narrow coronary arteries with much of the distal 2/3 of the left anterior descending artery a miniscule vessel. There were some scattered patches of atheroma. They had to swim against a strong surface current to reach the dive boat so it is believed that the effort involved proved too much for his cardiac function and cardiac failure occurred.

TRAINED. INEXPERIENCED. SURFACE SWIM IN CHOPPY WATER. STRONG CURRENT. SURFACE SEPARATION. NARROW CORONARY ARTERIES. POOR SURFACE COVER. NO INQUEST.

### SC89/4

A reputation for being experienced should always be taken as being valid only in regards to the specific activity being performed. In this incident the victim had great

experience as a hookah diver and he thought he would try scuba diving. He borrowed equipment and arranged to dive with a friend, but did not abandon his plan when the friend was not able to come as had been arranged. A witness saw him walking towards the water and later observed bubbles breaking at the surface when he returned to the beach.

The friend saw the victim surface twice more, apparently in some distress and having difficulty remaining at the surface. He therefore stripped off some of his clothing and entered the water. On reaching the spot he looked down and saw the victim sinking, head down. He was already 1.5 m underwater. He attempted without success to bring him back to the surface but found he was too heavy. He realised that the victim's weight belt and back pack had been ditched and were caught by the catch bag he had tied to his arm. Having no knife he was unable to cut this free so he had to attempt to tow him ashore, putting on the victim's fins to assist his swimming. The body snagged on the sea bed and it was only when another person arrived in a small boat that the victim was pulled to the surface.

SOLO. UNTRAINED. FIRST DIVE WITH SCUBA. EXPERIENCED WITH HOOKAH. OVERWEIGHTED. BORROWED EQUIPMENT. DITCHED WEIGHT BELT AND BACKPACK ENTANGLED ON CATCH BAG TIED TO ARM. NO KNIFE. NO BUOYANCY VEST. VALIANT RESCUE EFFORT.

### SC89/5

This victim was a visitor from the USA who had only recently arrived in Australia and gone straight to dive on the Barrier Reef. He correctly claimed to have been diving for 20 years but had got only 200 hours of logged dives, none in the previous 12 months, so was not truly as experienced as the 20 year history suggested. There was no history of any ill health. On the boat taking the divers out to the reef he was given a just-certificated diver as buddy because of his supposed experience. All were well briefed by the divemaster during the trip out and were also checked by him before they entered the water. The water depth here was 18 m maximum and all were told to ascend when their contents gauges showed 500 psi. After about 20 minutes the divemaster saw a lone diver surface, apparently in a normal manner, then became concerned when he saw that he was floating too quietly. He decided to check that all was well and quickly swam to him, about 30 m from the dive boat. The victim was floating face down with limbs outstretched. He turned him face up, ditched his weight belt, cleared his airway, and commenced EAR.

It was now that three divers surfaced nearby, the missing buddy with two others who she had joined when she was suddenly deserted. They had surfaced when the buddy had showed them her contents gauge indicated it was time for her to ascend. The victim was unconscious and cyanosed, with froth coming from his mouth. No pulse was

palpable even with CPR efforts. Resuscitation attempts were continued during helicopter evacuation to shore but he never responded. Because of delayed awareness by the police that this was a fatal accident (the victim was taken to a hospital), there was delay in requesting sealing of the equipment and it had been already disassembled and mixed with that used by others on the dive boat before an attempt was made to retain it. An arbitrary set was checked and while this showed some faults it was clearly not that used by the deceased. The fact that the equipment was imperfect allayed fears that a special effort might be made to present a perfect (but incorrect) set.

Before performing the autopsy some plain X-ray films were taken and these showed (supine) clouding of both lung fields and (erect) gas shadows in the region of both ventricles and the right coronary artery. When the great vessels were sectioned a large gas bubble was released. The aorta and coronary vessels were healthy and there was no evidence of recent myocardial damage. It was suggested that there was hypertrophy of the left ventricle and cardiomyopathy was diagnosed on the basis of this finding. A surprising suggestion was made that the widow had mentioned a history of ill health. This must be regarded as a doubtful finding.

TRAINED. EXPERIENCED 20 YEARS. NO DIVING PREVIOUS 12 MONTHS. SEPARATION THEN SUDDEN SOLO ASCENT. UNCONSCIOUS AT SURFACE. POSSIBLE ARRHYTHMIA ASSOCIATED WITH CARDIOMEGALY. CAGE. X-RAY EVIDENCE OF AIR EMBOLISM.

#### SC89/6

Following his basic training 6 years before he had suffered a serious road accident so had made only 5 dives since qualification, none being in the previous 12 months. He was stated to have made a complete recovery despite the prolonged period, about 2 weeks, of unconsciousness he had suffered. Aboard the dive boat there were in addition to him two other trained divers and a group of nine pupils with their instructor, his assistant, a trainee divemaster and a divemaster. It was recognised that the victim lacked experience so he was included for the first dive with five pupils and the instructor. Later, in the afternoon, he dived again, this time with four of the pupils who were making their first unsupervised dive. This, like the first dive, was without incident. They ascended carefully together and at the surface checked their remaining air. Three decided that they had sufficient to return underwater, the victim and one other being advised to surface swim return as they had less air. The buddy was quick to start his snorkel swim, looking back to the victim when reminded to do so by a shout from the boat. He was then 10 m from the victim, who was still where they had surfaced, 80 m from the boat. He appeared to be about to start snorkeling. Close to the boat the buddy dived using his remaining scuba air, and boarded the boat before again looking back. He saw the

victim floating at the surface "as if looking at fish underneath". Soon after this the other three divers surfaced 40 m from the boat, now low on air. They noticed that the victim was on his back, unconscious, a little froth coming from his mouth.

He was brought back to the boat and CPR resuscitation started but he failed to respond. The cause of death was found to be aspiration of vomit. He had not given any noticed signal of being in trouble.

TRAINED. INEXPERIENCED. NO DIVING PREVIOUS 12 MONTHS. SEPARATION AT SURFACE RETURN SWIM IN CALM WATER. ASPIRATION OF VOMIT. NO CALL FOR HELP. LOW AIR. GAUGE READ 200 PSI HIGH. INADEQUATE SURFACE COVER. PREVIOUS SERIOUS HEAD INJURY.

#### SC89/7

As a trained and experienced diver (7 years) this man had hired equipment from his dive club and taken it on holiday with his brother and a friend. He decided to make a solo dive, and after watching for a time as he kitted up, the other two left him in order to visit some of the local beauty spots. On their return at the agreed time they saw his back pack floating some way off the beach, in the bay, then observed the victim floating face down in waist deep water among the rocks. There was a cut in his left temple area but no significant bruising was noticed. All his detachable equipment was missing. The sea within the bay was relatively calm, though it was open sea, so he should not have been exposed to rough water. Although they believed that the victim was dead they made resuscitation attempts for the next 45 minutes.

The backpack was recovered later floating near to and bumping on rocks in the margins of a channel. It was left unwashed for several days by the finder and then, when nobody came to claim it, was taken to the police station. Formal examination was delayed for months. It was then noted to be showing corrosion and damage, though the person who reported on it was unwilling to accept that it could have been damaged on rocks in rough water conditions. The reason for this fatality was not established, though it appears likely that he experienced some problems and ditched his equipment, later suffering impaired alertness following a blow on his head. The autopsy showed neither drowning nor cerebral damage signs.

Of some interest was the Coroner's finding that the cause of this incident was a "sudden stoppage of air supply". This, he stated, "should have caused a sudden panic reflex action which prevented resumption of normal breathing, even when air was again available, until eventually asphyxiation was complete". It is uncertain who suggested such a scenario to him.

TRAINED. EXPERIENCED. HIRED EQUIPMENT. SOLO. DITCHED WEIGHT BELT AND BACKPACK. DELAY IN EXAMINATION OF EQUIPMENT. EQUIPMENT SHOWED DAMAGE.

#### SC89/8

Despite the opinion of one doctor that he was unfit to dive because of being overweight he had no absolute medical contraindications to diving and he was passed as Fit to Scuba Dive after a correct medical assessment. He had made over 90 dives without trouble and was now taking a Deep Diver Course and had previously passed an Advanced Diver Course. The dive was in a deep part of a harbour and involved an instructor with six pupils. On the bottom each demonstrated his basic skills (masks clearing, doff and don the equipment, buddy breathing) and they were then instructed to make a buddy-breathing ascent up the anchor line. Water depth here was 30 m and visibility was poor.

The buddy thought the victim was awkward with buddy breathing and when they reached about 18 m depth the victim changed over to the use of the buddy's octopus regulator, and at about 9 m depth he let this be loose in his mouth. The buddy pushed it back into his mouth in the correct position and they continued their ascent, the buddy replacing the regulator each time it was about to fall from the victim's mouth. Naturally, and correctly, the buddy omitted the planned (but not essential) deco step at 3 m and continued straight to the surface. From 9 m depth the victim did not appear to be alert.

At the surface the buddy noted vomit coming from the victim's mouth. The buddy inflated the victim's buoyancy vest and called for assistance. The victim was rapidly brought aboard the dive boat and it was there noted that he was not breathing and had a faint pulse. Resuscitation was commenced immediately with EAR, CPR being initiated when the pulse could no longer be palpated. This was continued until management was taken over by an ambulance crew.

The autopsy was conducted without adherence to the technique considered by diving medicine experts to be correct. Indeed the pathologist involved declared that the special diving-related approach to an autopsy was both dangerous and inaccurate. This view was neither explained nor justified by documentation quoting published papers. There was surgical emphysema in the tissue of the neck, thorax, and mediastinum but no air was noted in the heart or main blood vessels using the usual autopsy technique suitable for a non-diving death. The pathologist stated, in the report presented to the Coroner that "the findings are not inconsistent with dysbarism". What this pathologist intended to convey by this statement is not clear. There was no attempt to relate the findings to the clinical picture of the events. It is not unusual for a pathologist to fail to indicate the clinical significance of findings but this was exception-

ally maladroit management. Clinically this was typical of the underwater onset of cerebral arterial gas embolism (CAGE) symptoms. The lung histology showed severe oedema, congestion, and emphysema, with intra-alveolar, interseptal, and intra bronchial haemorrhages. Isolated fat emboli were noted in the capillaries.

TRAINED. EXPERIENCED. DEEP DIVER COURSE. PRACTICE BUDDY BREATHING ASCENT. BUDDY BREATHING FAILED DESPITE EFFORTS OF BUDDY. USED OCTOPUS REGULATOR FOR PART OF ASCENT. UNDERWATER ONSET OF CAGE SYMPTOMS. AUTOPSY PATHOLOGY REPORT SHOWED INADEQUATE KNOWLEDGE.

#### SC89/9

The participants of this Deep Diving Course had been prevented from diving for several days by bad weather so this was the first dive of the course, a shake down dive not involving specific tests or tasks. Both the victim and his buddy were experienced divers and the dive, on a wreck lying in water 33 m deep, was uneventful. They were tasked to check that the anchor was not trapped, which they did before starting their ascent after the planned 10 minutes. After ascending about 4.5 m up the anchor line the victim tapped his buddy as if to indicate some problem. The buddy assumed this was their rate of ascent, and as this was correct she continued ascending. She then saw that the victim was drifting away from the line and signalling for her to follow. She was able to persuade him, by signs, to return. He was then about 3.6 m away from the line. On returning to his buddy he removed the regulator from his mouth and appeared to desire to buddy breath. He showed no signs of panic and gave no "low air" signal. The buddy handed over her regulator and changed to her octopus (reserve) regulator. This provided her with poorer supply of air than her primary one and she took in some water. While she was recovering from this the victim released her regulator and started to ascend without a regulator in his mouth. The buddy, breathing rhythm upset and in near panic, now ascended rapidly and called for assistance on reaching the surface.

It was only after she had been retrieved and taken into the dive boat that anyone became aware that one diver was missing following an ascent problem. He had not been seen to surface so the skipper, an instructor, descended to search for him. He found blood in the water at 15 m and followed this down to the victim. He inflated the victim's buoyancy vest (he noticed inflation was slow) and noted that the contents gauge showed there was 150 atms remaining air. The autopsy revealed the presence of a left pneumothorax, gas in the left ventricle and inferior vena cava, and air mixed with blood in many vessels over the body. There was also gas in the peritoneal cavity. There was no pre-autopsy X-ray examination of the body. Clinical pulmonary barotrauma is an unusual finding and the frank loss of blood into the water is an exceptional finding. It was clear from his evidence that



the pathologist believed the reason for this massive air embolism was a too rapid ascent causing gas to be released from the tissue too rapidly. He was unaware of the different pathologies of CAGE and decompression sickness and failed to recognise hints, given him at the inquest, that he was incompletely informed on such matters.

Examination of the equipment revealed that the buddy's reserve (octopus) regulator was indeed hard to breath, while the problem which affected the victim was more complex in nature. He had recently bought a new second stage regulator and this required a higher line pressure than had his previous one. This mismatch of makes resulted in the air supply being much impaired. In addition he had a J-valve on his tank which was significantly reducing the air flow. As a consequence the filling rate of his buoyancy vest was being slowed by both the effects of depth and impaired air flow rate. This may have made him think his vest was inoperative, as he failed to inflate it, and that his air supply was near exhausted.

It was noted during testing of the equipment that the contents gauge reading fluctuated with each breath from showing half full to indicating nearly empty. If he observed this it should have alerted him to an obstruction to the flow of air from his tank.

TRAINED. EXPERIENCED. DEEP DIVE COURSE. NO RECENT DEEP DIVES. MISMATCH OF FIRST AND SECOND STAGES REDUCED AIR FLOW. J VALVE REDUCED AIR FLOW. FAILED TO DITCH WEIGHT BELT. SLOW FILLING BUOYANCY VEST AT DEPTH. NITROGEN NARCOSIS FACTOR. PANIC/ ANXIETY FACTORS. FAILED BUDDY BREATHING ASCENT. MASSIVE CAGE AND PNEUMOTHORAX. PNEUMO-PERITONEUM. HAEMOPTYSIS. BUDDY HAD PROBLEM WITH POOR OCTOPUS REGULATOR AIR SUPPLY.

#### SC89/10

The dive involved three divers with tanks of different capacities (72, 88 and 98 cu ft), the victim having the one with the largest capacity. Towards the time for ascent they found an anchor and, as he had the most remaining air, the victim was deputed to remain with it while the other two surfaced, one to remain "on station" to mark the position while the other swam to their boat and brought it back. This was to facilitate the recovery of their prize. However, they were unable to locate either the victim or the anchor and had to assume that a surface current had foiled their scheme. As both were now out of air they had to call for assistance with a search for the missing diver, but this search was unsuccessful. The body was found the next day. It was only after the incident that the buddies heard that he was an epileptic who was on regular medication of this condition. Although it was later stated that he had suffered no attacks for 14 years another deposition stated that he had fits if he omitted treatment for a time. He had been seen to take a tablet,

presumably this medication, on the day of the fatal dive. It is nevertheless possible that he suffered a fit while alone on the sea bed. There was no mention of teeth marks on the mouthpiece but these would not occur if it fell out at the onset of symptoms.

When found, the victim's tank was empty but this cannot be taken as proof that he was indeed out of air when he died. The tank may have been low on air and emptied later. He was not wearing a buoyancy vest although he had one. He had left it in the dive boat. The weight belt was still in position, as was the rest of his equipment, when he was found.

The autopsy showed no evidence of drowning or that he had suffered an epileptic fit, according to the pathologist. The histology of the lung revealed the presence of disruption of the alveolar spaces with associated intro-alveolar haemorrhages and oedema suggestive of pulmonary barotrauma. Surgical emphysema was noted to be present in the precordial region of the chest. Despite his earlier comments, the pathologist gave as his conclusion that death was consistent with epilepsy after scuba diving.

An examination of the equipment showed that the clamp securing the mouthpiece was loose and allowed the entry of a fine spray of water with each inhalation. This was described as not sufficient to cause any distress, but the victim was not very experienced and it may have played some part in the incident.

TRAINED. SOME EXPERIENCE. TRIO DIVE GROUP. UNEQUAL SIZE OF TANKS. ATTEMPTING SALVAGE OF ANCHOR. DELIBERATE SEPARATION UNDERWATER. EPILEPTIC ON REGULAR MEDICATION. LOW AIR (PROBABLE). LOOSE CLAMP ON MOUTHPIECE SO FINE SPRAY SALT WATER INHALATED WITH EACH BREATH. PATHOLOGIST REPORTED BAROTRUAMA SIGNS, BUT IGNORED THEM IN HIS FINDINGS. PROBABLE CAGE. NO INQUEST.

#### SC89/11

This dive was made from rocks, the buddy swimming out first and waiting for his friend to join him. The victim had been diving for 14 years and talked about his overseas experiences so that his buddy was assured of his competence, though he had never been trained so held no certification. The buddy remained about 20 m from the rocks and watched as the victim swam out for 10-15 m then stopped and lifted up his mask. The sea was calm and conditions suitable for a safe dive. The buddy called out to him to replace his mask and look down at the king fish, but received no reply so swam over to him to find out what was the matter. He was told "I don't feel right" and the buddy observed that he looked frightened, red faced and agitated. He asked for his regulator, which was handed to him. The buddy tried to calm him and supported him as they drifted in the direction

of the beach.

The buddy suggested that they swim a little further and so reach the beach but the victim declined this suggestion and looked very distressed and declared his wish to return to their point of water entry on the rocks nearby. The beach was 200 m away, the rocks far closer. The buddy towed the victim to within 3 m of the rock platform. Here the victim said he was feeling very tired so the buddy comforted him and told him to keep his mask on and the regulator in his mouth and to swim to the rocks. He assured him that he would be close behind him. There was no apparent reply but he responded in an unexpected manner, beginning to swim in the opposite direction, head down and kicking with his feet. The buddy was feeling too tired to follow but shouted out to him. He saw him reach some rocks and climb onto them, so assumed that all was now right with him, so he now exited, which he found difficult because of his tiredness.

A short time later he saw his friend floating on his back 20 m away, being washed about over the rocks by the incoming tide. He managed to just grab him while standing on a small rock platform but lost his grip on the victim's buoyancy vest while unsuccessfully trying to ditch the backpack and the weight belt. The weight of the fully kitted up victim combined with the surge of the water proved too great and he lost contact with the victim. A call for assistance brought the helicopter rescue team and the victim was recovered 20 minutes later. Resuscitation attempts were unsuccessful.

The autopsy showed that the coronary vessels were healthy and almost free from atheroma for a plaque in the circumflex branch of the left coronary artery at the junction of the proximal and middle thirds. This had a smooth surface and appeared to narrow the lumen by 40-50% but there was no evidence of infarction. There was no history of ill health.

EXPERIENCED. UNTRAINED. SURFACE ILL HEALTH SYMPTOMS AFTER WATER ENTRY. VALIANT ASSISTANCE BY BUDDY. SEPARATION FOR EXITING ONTO ROCKS NECESSARY. PROBABLE CARDIAC CAUSE DEATH. FAILED TO DITCH WEIGHT BELT. FAILED TO INFLATE BUOYANCY VEST. BUDDY FAILED TO DITCH VICTIM'S EQUIPMENT DUE TO WATER POWER.

#### SC89/12

This overseas visitor had been diving for several years but there is no information concerning the nature and degree of his experience. He was with a group of his compatriots on a diveboat trip to the Barrier Reef from their hotel. During the trip to the dive location the group was given a talk by the divemaster which was made against a background of chatter which required several calls for order from the divemaster. An interpreter was present but it is uncertain whether he was translating the instructions and descriptions concerning the dive. Shortly after entering the

water with the group the victim returned to the dive boat with his buddy and complained of some problem with his regulator or mask (reports differ). The only problem identified was an over tight chest strap, which was loosened. However he then declared that he would remain on the boat and not dive, so his buddy swam back and rejoined the group. At this time someone drew the divemaster's attention to the fact that the anchor was dragging and after he had corrected this he saw a solo diver swimming away from the boat in the direction taken by the main group earlier. He assumed the victim had changed his mind about making a dive while still on the dive platform at the stern.

The victim failed to make contact with the others and it was only when a roll call was taken after the return of everyone else that his absence was noted. A helicopter made a search of the surrounding area and he was found floating near the reef. He had ditched his equipment but his backpack was found at a later date. Despite vigorous attempts to resuscitate him there was no response. This was not surprising because the pre-autopsy X-ray and CT scans revealed the presence of massive air entry into the vascular system and the tissues. There was no sign of illness.

An investigation was made by the staff following this death and several points were made of value to dive operators. There was the factor of over-confidence by the group members with consequential poor attention to the pre-dive instructions. There may have been language block to communications, despite the presence of the interpreter. An absence of "pagers" for critical personnel delayed the organisation of the response to the "lost diver" alarm, and the dive boat Oxy-viva lacked an oxygen cylinder. It was also noticed how partiality of analysis could impair an in-house investigation close to the time of a tragedy. These comments underline the importance of maintaining a ready-response state while conducting dives.

It is naturally impossible to know what actually happened but the victim had mentioned that he did not feel well prior to the dive (but had not cancelled his scuba dive). The factor of amour-propre may have influenced his actions, a factor in many diving situations.

TRAINED. EXPERIENCE UNDOCUMENTED. SEPARATION/SOLO DIVE. DELAY IN RECOGNITION THAT HE WAS MISSING. DITCHED ALL EQUIPMENT. PULMONARY BAROTRAUMA. CAGE. MINOR FAULT IN EQUIPMENT (OCTOPUS REGULATOR LEAKED AIR). POSSIBLY PANIC AND OUT-OF-AIR ASCENT. PRE-AUTOPSY X-RAY AND CT CHECKS.

#### SC/13

The victim had been scuba diving for 3 years although he was untrained. No details of the training or experience of his two companions is recorded. They swam

to a reef and there started diving for crayfish. The victim and one of the others had a catch bag and the third diver swam with his catch to whoever was the nearer. The victim was also carrying a spear gun. After 30 minutes one of the trio returned to the shore and was followed 5 minutes later by the other, leaving the victim diving alone on the reef. They saw him at the surface at this time, then lost sight of him. When he failed to reappear after a further 10 minutes they became anxious and swam out to where they had last seen him. They found him floating face down at the surface, minus his weight belt and with his backpack unbuckled and half off. The water was murky and somewhat rough at this time.

They brought him back to shore and attempted to resuscitate him but were unsuccessful. His tank still contained 100 bar when it was checked later. He was not wearing a buoyancy vest and had not called for assistance as far as his companions were aware. The reason for his drowning is not known but fatigue, the water conditions, absence of any buoyancy aid and the aborted attempt to ditch his backpack (not usually a helpful option) were probable contributory factors. It is possible that he was distracted at a critical moment by the loosened backpack after unintentionally opening its buckle.

UNTRAINED. EXPERIENCED. TRIO GROUP. SEPARATION/SOLO. CRAYFISHING. ROUGH WATER. PROBABLE SURFACE PROBLEM. SOME REMAINING AIR. DITCHED WEIGHT BELT. PARTLY LOOSE BACKPACK.

### **H89 1 and H89/2**

This double fatality occurred on a pearl farm lease while the trays of pearl shells were being cleaned and checked. One of these divers was young and newly (scuba) trained, but the other was an experienced diver who had learned the craft from a previous employee when he first came to the job. This was considered a normal way of learning to dive. There were six divers working as teams of two on different areas of the underwater racks and the tragedy was discovered when the others met for a work break and noticed their absence and the silence of the compressor which was supplying them with air. They had been working at depths of 15-18 m and could be up to 9 m apart while working, supplied by from the compressor in their launch. The older of the two victims was acting as the instructor to the younger, who had only recently been employed. They usually worked for about 2 hours at 15 m but this might be extended by the divers, as happened this day.

There were no bubbles and the two hoses down showed that the divers were still underwater. The other divers pulled them to the surface and attempted, without success, to resuscitate them. It was later established that on the previous day the older man had complained about the bad taste of the air and had been given another compressor. But this unit had no intake pipe and he was told to take one off

the compressor he was returning. This he was unable to do because it was too rusted in place to remove. The compressor was placed against the wall of the steering unit, beneath the canopy which partly covered the boat. The sea was calm and there was only a slight breeze and the exhaust fumes had been drawn into the air intake. It was noted that none of the Diving Safety Regulations were being observed and that the divers employed were untrained and usually failed to obtain treatment when they suffered from an episode of decompression sickness. This situation was well known to the authorities and permitted to continue. The District Medical Officer for the area, like his colleague in another pearl diving area in previous years, had attempted to draw attention to the need for training and better conditions but achieved nothing in the face of economic realism.

Investigations confirmed that the cause of death was carbon monoxide poisoning due to the incorrect placement of the air intake drawing the compressor's exhaust fumes into the compressor.

DOUBLE FATALITY. EXPERIENCED DIVER UNTRAINED. INEXPERIENCED DIVER RECENT SCUBA COURSE. NO SURFACE TENDER IN BOAT. BADLY MAINTAINED EQUIPMENT. INCORRECT POSITIONING OF AIR INTAKE. CARBON MONOXIDE POISONING. OFFICIAL TOLERANCE OF UNSAFE PRACTICES.

### **H89/3**

This case also illustrates the dangers of a malpositioned air intake hose when using a compressor-supplied hookah unit. The victim was an abalone diver but the tragedy occurred while he was diving in the calm waters of a harbour doing a favour for a friend whose mooring had been disturbed during a recent storm. Indeed his compressor was in his boat on its trailer on the wharf during this dive. He made an initial dive to assess the problem, surfaced to ask for some chain and tools, then dived again. His assistant, his "sheller", was with the boat as his tender and during the time of the first descent a passer-by mentioned to him that the air hose intake was inside the boat rather than hanging over its side, so liable to suck in exhaust fumes from the compressor's engine. This was corrected. The sheller realised that it must have become displaced while the boat was removed from the water and placed on the trailer, or during the short drive onto the wharf.

The sheller became alarmed when he noticed that there were no bubbles breaking the surface. He stripped off and dived in to find out what had happened, surfacing in alarm after discovering the unconscious form of his boss. Another person pulled the victim to the surface. He was obviously beyond the reach of resuscitation and no attempts were made to perform this. The autopsy confirmed the diagnosis of carbon monoxide poisoning. If the story was given correctly the air supplied to the victim for his second

descent should have been "clean" and he would have been expected to escape with a headache. Either the contaminated air from the reservoir tank compromised his survival or the dose received during his first descent had a delayed, but fatal effect. This matter was not discussed at the inquest.

SOLO. ABALONE DIVER WORKING ON HARBOUR MOORING. COMPRESSOR IN BOAT ON TRAILER ON WHARF. MALPOSITIONING OF AIR HOSE INTAKE NOTED TOO LATE. CARBON MON-OXIDE POISONING.

### Discussion

These cases serve as a reminder that diving takes place in an environment which can be unforgiving of deviations from the rules of safe diving and where problems can rapidly progress to a fatal outcome. It is important to be aware of what may occur so that similar events can either be avoided or their effects minimised. Such is the purpose of reports such as this.

The breath-hold fatalities, which are fortunately few in number, show that post-hyperventilation blackout can kill an experienced and determined diver even in shallow water close to friends. The cardiac death may be regarded as an unavoidable risk faced by all who live, but the attempts made by his buddy to save him illustrate the vital place of a buddy in assuring survival should the course of events be not irretrievably set on a fatal outcome. The other victim was probably the recipient of a blow on his head from a powerful fish, a most unusual and "unjust" accident.

In the group of scuba divers who died, as far too many did, there are a number of findings worth consideration. Naturally the question of whether the separated and solo divers prejudiced their chances of survival by having no buddy at the critical time will continue to vex many. Where present, all the buddies performed valiantly, though from the nature of this series none were successful in saving their companions.

It was not surprising, though not really acceptable, that a group of instructors ignored all the rules of buddy diving "because it was an informal dive and there were no paying customers".

Health as a factor is of uncertain importance in the prevention of fatalities. The only diver with a history of asthma was apparently never adversely effected by it while diving, though his practice of performing a pre-dive flow-rate check indicates an incomplete understanding of the risk he ran should he inhale a fine spray of salt water. The diver with the history of epilepsy should not have been diving. It is probable that his condition was less well controlled than he admitted. Whether any of the divers where a cardiac factor was implicated would have been identified by a

routine pre-dive medical is unknown but probably they would not.

Equipment problems were not in themselves necessarily fatal but they contributed to several incidents. A fine spray of sea water with every inhalation may be tolerable but it can have adverse consequences, and a high-reading contents gauge may allow a diver who budgets on too low an amount of remaining air before deciding to ascend to find himself with a serious low-air problem. One matter of significance was the experience of the buddy who found that the secondary (octopus) regulator was hard to breath. During an emergency is not the ideal time or place to discover such an imperfection. It would seem to be a good idea to try out one's secondary regulator from time to time so as to avoid any such surprise. An important matter which was identified was the possible serious consequences of a mismatch of different makes of first and second stage regulators if the second stage requires a higher line pressure that the first stage provides, for optimal functioning. This fact is probably unknown to many who have come to no harm but blamed the equipment they had bought. However, it should be remembered that this diver should have been dissatisfied by his demand valve's function and not accepted it, and should have regarded the wild fluctuations of the needle of his contents gauge as giving him an imperative message to ascend immediately. Possibly he did not consult his gauge so missed the warning it gave.

The number of cases where pulmonary barotrauma or air embolism (either proved or clinically probable) had occurred was a surprise and must contain a message concerning diving practices of the present day. It should be noted that it can occur without the victim reaching the surface or even closely approaching it. In this matter the author has used his reading of the evidence on occasion in preference to accepting the views of the pathologist involved in the case. There are still some pathologists who are unaware of their ignorance of diving-related causes of death, and unfortunately they are deaf to the polite advice of the police witnesses. In one instance even the performance of a "diving" autopsy did not prove to indicate an understanding of the matter in hand. As Coroners are usually obliged to follow the finding of their "expert witness, the pathologist" there can be imperfect inquest findings. There were more occasions during 1989, than in previous years, where these observations were relevant and it is for this reason a public comment is made.

Although there has been an increased incidence of cases where the Coroner has considered an inquest to be not necessary, this would be of no great moment was there not a simultaneous policy change of the coronial records of such cases not including copies of the police-supplied evidence on which the decision was based. While the primary function and responsibility of the Coroner is to examine the cases of "accidental" death, to establish or exclude the presence of some criminal acts, it is now recognised that there is an equally important function served, the investiga-

tion of such occurrences by the police acting as agents for the Coroner. The information so collected can assist the recognition of critical factors in some fatalities and thereby make it possible to devise strategies to avoid their repetition or to mitigate their consequences. Without the resource of case documentation prepared for the Coroners it would not be possible to undertake surveys such as this.

Divemasters and those who are responsible for others may find it helpful to consider the recent as well as the total experience of those in their case. They may also remember the importance of keeping an effective watch on the surface where divers may appear and require assistance. In two instances an unconscious diver was not initially noticed. In another an alert divemaster noted the unusual quietness of a diver and immediately investigated. Had the diver not suffered an inevitably fatal CAGE, his action would have been life saving.

The dangers of carbon monoxide to hookah users are well known and these three deaths underline the serious consequences which may follow the intake of exhaust fumes into the compressor. While this gas itself is odourless it is possible that a refusal to dive when the air has any odour could be a wise safety move. It is regrettable that the investigation of the double tragedy revealed that there has been no improvement apparent in the application of diving safety regulations to the pearl diving industry over several decades. The District Medical Officers at Thursday Island and Broome have commented on the situation on occasion without apparent effect. Possibly matters will change with the increased attention to the diving industry by the various Workplace Health and Safety Officers. Thoughtfully applied, such attention would be of real long term benefit to many commercial divers.

## Conclusions

The dangers of post-hyperventilation blackout are again confirmed. The only way to prevent the victim drowning would be by a change in attitude on the part of such divers and the use of surface observers of them during their dives. Such an attitude change is unlikely.

Scuba divers are reminded of the importance of checking their equipment and not tolerating demand valves which let in water or regulators which are hard to breathe from. They should be profligate with their air, ascending while having sufficient remaining air for any emergency. They should seek to never place themselves in a situation where a buddy breathing ascent is the only option as this can end fatally. The practising of such ascents is therefore not advisable. The importance of an efficient surface cover, of recent diving experience, and presence of a buddy nearby should one get into trouble are all desirable propositions.

The Coronial Investigation system is of great value

and information derived from it is invaluable in improving our understanding of the critical factors in diving safety.

The importance of informed pathology investigation of diving-related deaths is again stressed.

## Acknowledgements

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## MULTI-LEVEL RESTRICTIONS WITHIN THE US NAVY TABLES

Bruce Wienke and Dennis Graver

### Abstract

Schemes for multi-level diving are employed in the commercial, scientific, and sport sectors. One approach employs back-to-back repetitive sequencing, assigning groups at the start of each multi-level dive segment based on the total bottom time (actual plus residual nitrogen) of the previous segment. At times, that method allows critical tensions, other than the controlling (repetitive) 120 minute compartment tension, to be exceeded upon surfacing. In the context of the US Navy tables, such a circumstance is suspect. But by tightening the exposure window and accounting for ascent and descent rates, such a multi-level technique can be made consistent with the permissible tension formulation of the US Navy tables. In studying this multi-level technique, we can draw a line (envelope) across the Repetitive Group Table, separating dives violating at least one critical tension at some point in the multi-level sequence from those not violating any critical tensions. Ascent and descent rates of 60 feet (18 m)/min are assumed, and the envelope also maintains tissue tensions below critical values throughout the multi-level dive. Some 16 million multi-level dives were analyzed on a CRAY supercomputer, permitting construction of the dive envelope. The standard US Navy sets of tissue half-lives and critical tensions were employed. The envelope moves non-stop time limits back a group or more in the US Navy tables, restricting the back-to-back repetitive method in the same measure. Restrictions are straightforward and simple for possible wet testing.

### Introduction

To evaluate multi-level diving adequately within any set of tables, it is necessary to account for ascent and descent