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SCUBA DIVING INCIDENT REPORTING THE FIRST 125 INCIDENT REPORTS

Chris Acott

Introduction

Errors ("performances which deviate from ideal")[1] are a part of our everyday existence.[2] The majority of these errors are usually trivial, of no significance, recurring and preventable.

Accidents are errors "with sad consequences"[3] and occur in a system which is "tightly coupled"[3] and so not forgiving. Research in aviation, the nuclear power industry and maritime transport accidents has shown that accidents are rarely produced by a single cause but usually by a host of interacting ones. Accidents are, therefore, the consequence of a group of errors, or a collection of interacting negative incidents.

Incident reporting

Incident reporting involves the study, reporting and analysis of error. When applied to human performance it deals with human error.[2],[4-7] It examines the contributing factors and associated patterns.[4,5] These factors and patterns have received little attention in accident reporting,[1-3] and their elimination will ultimately reduce error[2] (see Figure 1).

Corrective strategies are designed to eliminate these contributing factors and associated patterns.

Incident reporting involves several steps:

1. Recognition: realizing that an incident, although thought to be trivial, has occurred, and that it may have some important implications.
2. Reporting: writing down the story of the incident and sending to the collector. This is helped by using a standard form.
3. Collection: there must be a focus point to which the reports are sent.
4. Analysis: patterns and factors in the reports must be identified.
5. Formation: corrective strategies are formed aimed at the elimination of the patterns and factors identified by analysis.
6. Feedback: the information is widely distributed in the community for utilisation.

In the 15 months from January 1989 to March 1990, 125 incidents were reported to the Diver Incident Monitoring Study (DIMS) which is based at the Hyperbaric Medical Unit, Royal Adelaide Hospital. Forty of these incidents (32%) were associated with morbidity.

Contributing factors

The common contributing factors for these incidents

FIGURE 1

THE COCK-UP CASCADE

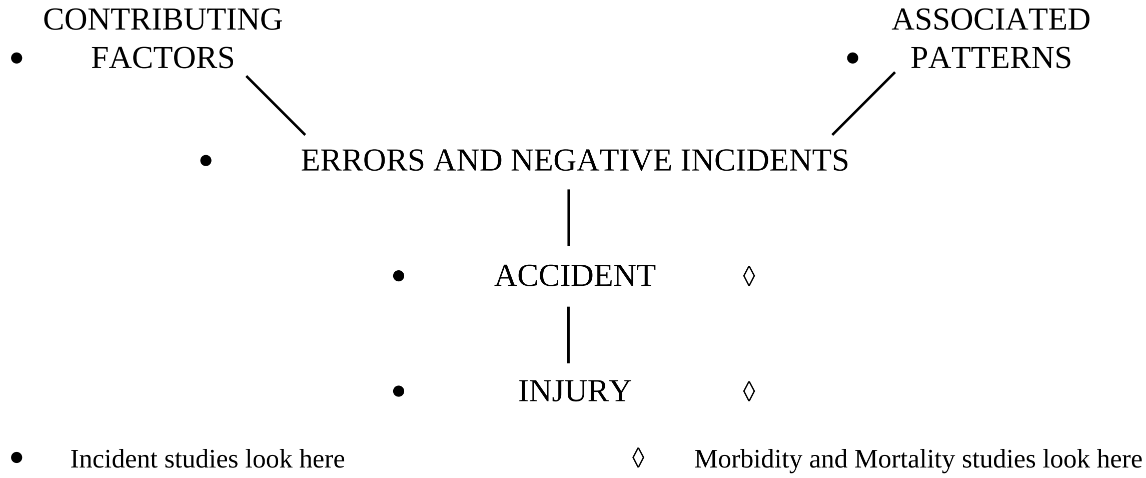
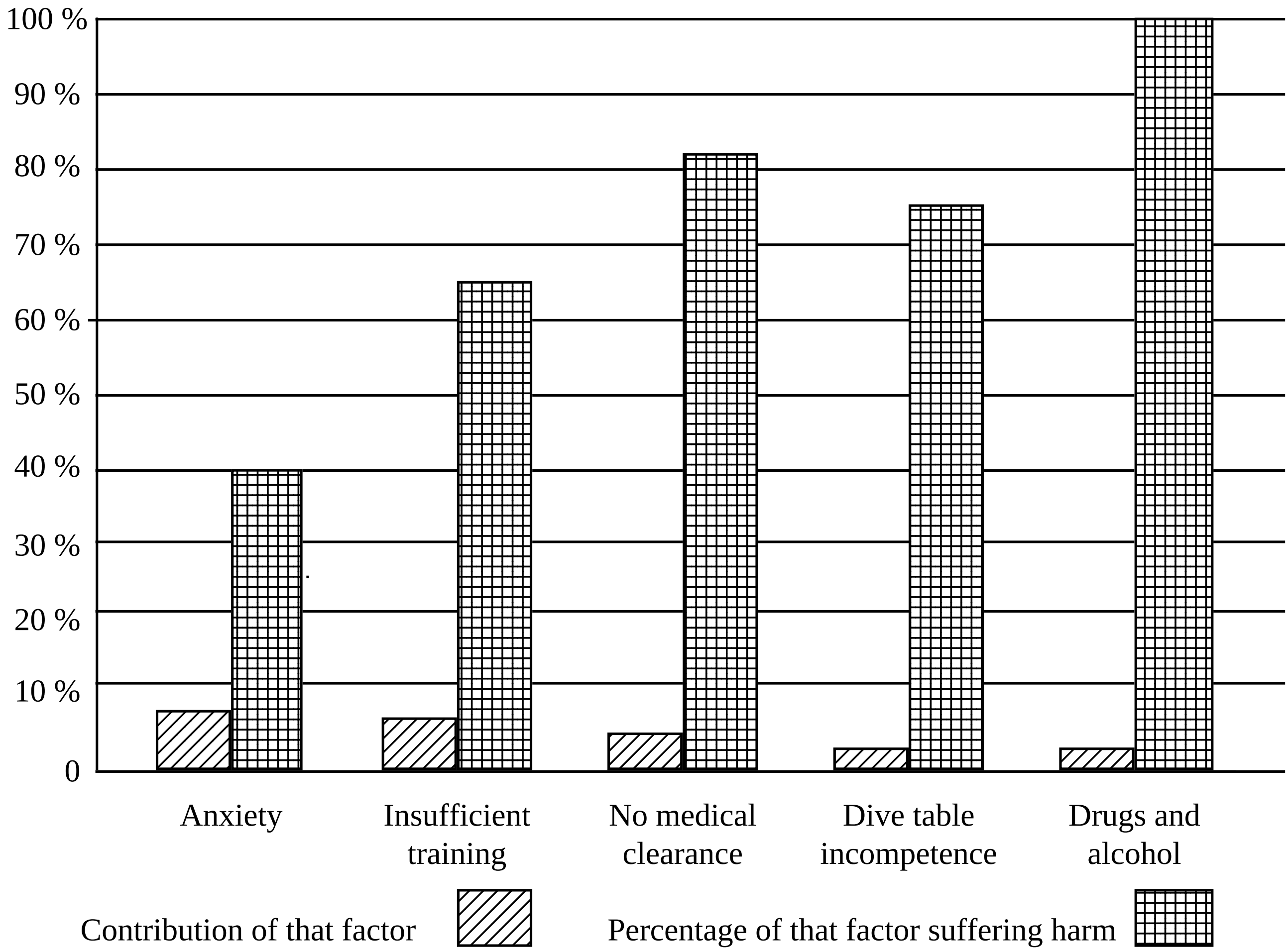


FIGURE 2

UNCOMMON CONTRIBUTING FACTORS LEADING TO HARM



were errors of judgement, poor dive planning, inexperience, inattention and diving in unfamiliar conditions

Morbidity

There were a number of less common contributing factors, anxiety, failure to understand the dive tables, drugs including alcohol, insufficient training and lack of a medical clearance, which when present were associated with diver harm. Table 1 shows to the associated morbidity.

In one diver, hospitalized for salt water aspiration, acute renal failure developed 48 hours later. The salt water aspiration caused a pneumonitis and right lower lobe collapse. No cause was found for his renal failure. He was treated conservatively and left hospital with normal renal function. He has since given up diving. The pulmonary infection followed breathing from a contaminated buoyancy jacket. Pseudomonas was cultured from the mouth piece.

TABLE 1

MORBIDITY REPORTED

DCS		14
Barotrauma		13
Ear	7	
Pulmonary	4	
Sinus	2	
Salt water aspiration		7
CAGE	4	
Coral sting		4
Right lower lobe collapse		1
Acute renal failure		1
Pulmonary infection		1

Cerebral arterial gas embolism (CAGE) was associated with two cases of salt water aspiration. However in this series, pulmonary barotrauma was not associated with detectable CAGE.

Experience and training

During training there were six incidents which resulted in harm. Equalization and shared breathing techniques predominated. One diver developed transient symptoms of CAGE after a swimming ascent but failed to report his symptoms to his instructor. His symptoms were no longer transient after his second dive.

Errors were not confined to the inexperienced diver. Table 2 shows an equal distribution between experienced and inexperienced divers.

Incident detection

The majority of the incidents (46%) were detected during the dive.

Distribution of incidents associated with morbidity

Thirty (75%) of the 40 harmful incidents were detected during ascent and following the dive (Figure 3). Any incident that was detected during the ascent or following the dive was associated with considerable morbidity (Figure 4).

It was fortunate that the problems associated with handling of weight belts at the exit were not associated with morbidity. The dropping of weights (and weight belts) when leaving the water can have disastrous consequences on those below.

In 13 of these incidents divers reported that the management of the situation would have been helped by an alternative air supply. Four of the shared breathing situation resulted in salt water aspiration. Five of the out of air situations involved an inaccurate contents gauge.

Equipment problems

The majority of the 67 equipment incidents involved either the diver's regulator or buoyancy jacket.

FIGURE 3

WHEN INCIDENTS WERE DETECTED

FIGURES ABOVE COLUMNS ARE THE TOTAL NUMBER OF INCIDENTS REPORTED IN THAT STAGE OF THE DIVE

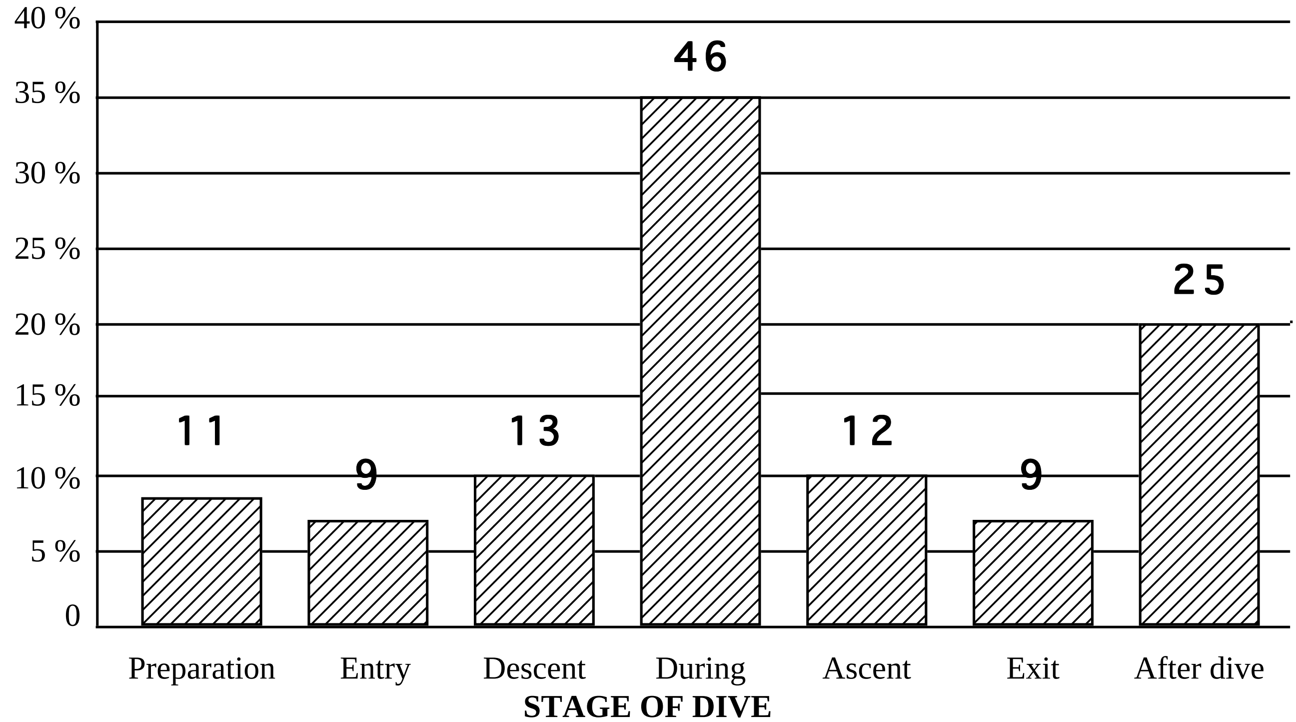


FIGURE 4

DISTRIBUTION OF INCIDENTS ASSOCIATED WITH HARM BY STAGE OF DIVE

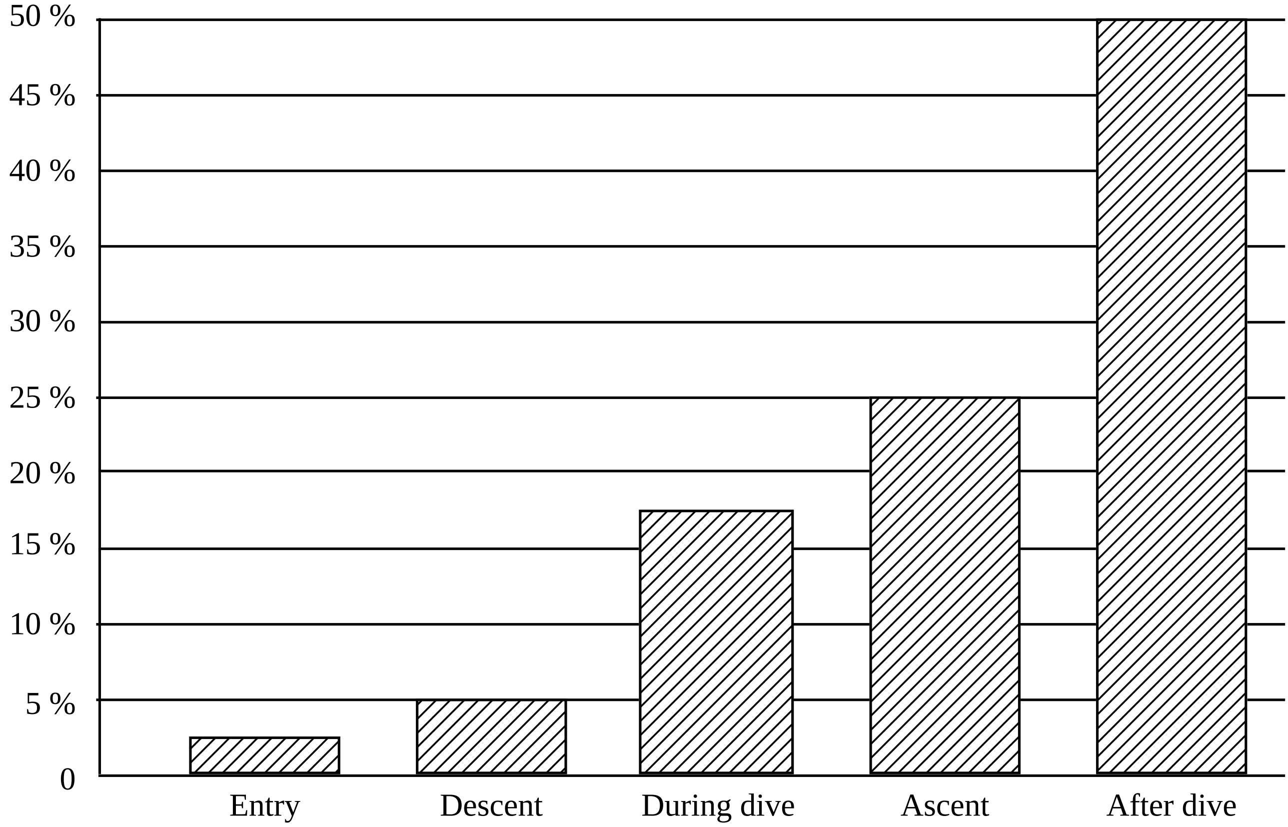


FIGURE 5

ALL INCIDENTS AND PERCENTAGE CAUSING HARM BY STAGE OF DIVE

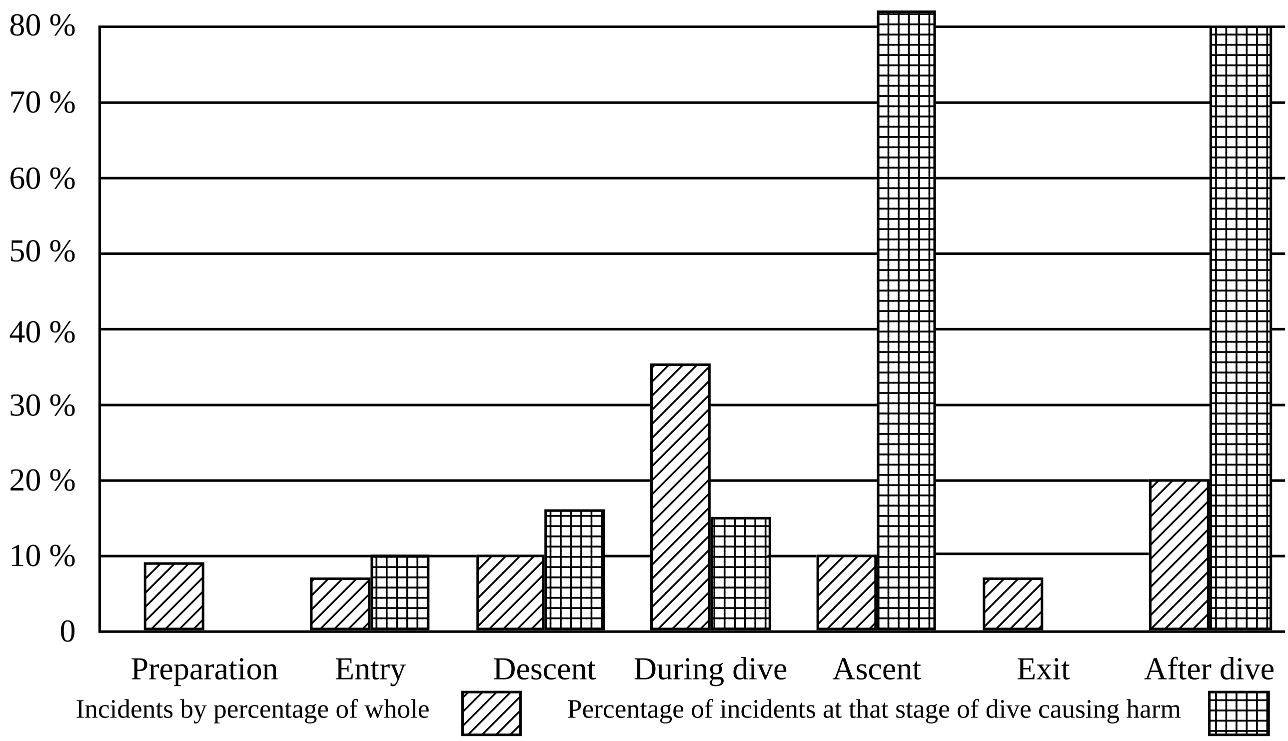


TABLE 2

EXPERIENCE LEVEL OF DIVERS INVOVLED IN INCIDENTS

Untrained	7
Under training	8
Basic	34
Open Water	37
Advanced	22
Dive instructor	11
Commercial	2
Unknown	14
Total	**135**

TABLE 6

AIR SUPPLY AND REGULATOR PROBLEMS

Inaccurate contents gauge	5
Free flowing 2nd stage	5
Misplacement of octopus	3
Rupture high pressure hose	3
Leaking high pressure hose	1
First stage blow out	1
2nd stage jammed	1

Equipment failures

Seventeen equipment problems did not involve diver error, and so could be considered as being pure equipment failure. Table 5 shows that pre-dive checks are not being executed, or if they are, they are brief and poorly conducted.

Oxygen equipment

In 5 incidents, where oxygen was available for the First Aid management, either the oxygen supply was inadequate or nobody was familiar on how to use the equipment. In all 5 incidents the concentration of oxygen achieved would have been far less than 100%.

TABLE 3

OUT-OF-AIR AND LOW AIR INCIDENTS

Out-of-air		9
Inacurate contents gauge	5	
Low air to out of air		5
Low air		4
Total		**18**
Coping strategies		
Octopus breathing		10
Water aspiration	3	
Buddy breathing		3
Water aspiration	1	
Direct ascent		6

TABLE 4

EQUIPMENT PROBLEMS

Regulator	19
Buoyancy compensator	18
Weight belt or weights	8
Wet suit	6
Fins	5
Air supply	5
Depth gauge	3
Mask	2

TABLE 5

BUOYANCY JACKET PROBLEMS

Unfamiliar with its use	4
Scuba feed not attached	4
Incorrect use	3
Tank not secured correctly	3
Unable to vent vest	2
Vest leaked	1
Inflation device failed	1

TABLE 7

EQUIPMENT PROBLEMS DETECTABLE BY BUDDY AND PRE-DIVE CHECKS

	Total problems	Detectable by buddy check	Detected by buddy check	Detectable by pre-dive check	Not detectable by pre-dive check
Regulator	19	14	1	14	5
Buoyancy compensator	18	15	1	11	2
Weight belt or weights	8	3	0	4	3
Wet suit	6	0	0	3	4
Fins	5	1	1	1	0
Air supply	5	5	1	5	0
Depth gauge	3	3	0	3	0
Mask	2	0	0	0	2
Dive computer	1	0	0	0	1

Discussion

Equipment problems predominate in this series of incidents. Misuse, misassembly, failure to check and lack of understanding of how the equipment functions all featured. Diving is an equipment dependent sport and a diver's interaction with his equipment is an important aspect of safety. The majority of the equipment problems related to buoyancy jackets and regulators.

This series shows 3 disturbing features.

1 A quarter of the regulator problems would not have been detected by any immediate pre dive check.

2 There was either an absence of or a poorly executed buddy check.

3 Inaccurate contents gauges were an important contributing factor in the out of air situations.

All the buoyancy jacket incidents were due to diver error. How to inflate and deflate the jacket, especially in emergency situations, and the correct function and use of the jacket do not appear to be well understood. Allied to this, correct weighting appears to be lacking, leading to uncontrolled or unplanned alterations in buoyancy, which can carry potentially serious consequences.

This study correlates well with other studies of human error by showing that the thorough checking of equipment ("check lists") before use is an important aspect of safety.[2,5,7] Pilots have a "cockpit drill", why not divers?

There has been little emphasis focussed on the accuracy of contents gauges in mortality reporting.[13] Once a gauge is sold it is seldom recalibrated or serviced. Inaccurate contents gauges were cited as an important cause of the "out-of-air situation". Reintroduction of the sonic reserve (the first stage regulator emits a noise with each breath when the cylinder pressure is low) could be an important safety measure. Irrespective of what the contents gauge shows the diver would know that he or she is low on air.

Sudden loss of air supply (due to first stage blow out or rupture of a high pressure hose) can have disastrous consequences. An independent alternative air supply would have made the management of these situations easier. But the alternative supply has to be an effective one, enabling the diver to get to the surface in all situations. An additional piece of equipment means more equipment to be checked before the dive, and this study has highlighted the lack of good pre-dive checking!

This study correlates well with other studies showing that alcohol increases the injury risk with aquatic sports.[8-10] Diving and alcohol do not mix!

Shared breathing techniques were a major cause of salt water aspiration. Poor technique when clearing the second stage caused problems leading to water being inhaled.

Understanding decompression table is pre-requisite for safe diving. Divers should be taught a set of tables thoroughly during training, and eligibility to dive should be based on their understanding of them and being able to work out the correct answers for single and repetitive dives. Knight[11] and later, Wilks and O'Hagan[12] showed that a high percentage of recreational divers lacked fundamental knowledge of decompression tables (even in a so called "well educated" group of divers).[11]

There is a correlation between the lack of medical fitness to dive and morbidity in this study.

The first aid management of diving accidents requires administration of 100% oxygen. Knowledge about how to achieve 100% oxygen and the equipment to use is lacking in the Australian diving community.

Divers should plan their exit from the water. Mishandling of weight belts at the exit may have disastrous consequences if another diver is underneath it.

Corrective strategies

DEVELOPMENT OF CHECK LISTS

Each diver should inspect and test their own and buddy's gear, especially inflation and deflation of the buoyancy compensator (BC), quick releases, air supply connections and safety devices. Each diver should carry a check list in his or her diving bag.

A check list should include the following:

BUOYANCY COMPENSATOR

1 Check the scuba feed is connected and will inflate and deflate.
2 Check the jacket for leaks when fully inflated.
3 Check oral inflation.
4 Check the emergency vent holes.
5 Check the tank is secure in the back pack.
6 Check that the buddy divers know where everything is located on both divers and are able to use them.

REGULATOR AND CONTENTS GAUGE

1 Switch air supply on. Note the full position on the contents gauge.
2 Switch air supply off.
3 Check the purge button (of both second stages if fitted with an octopus) works.
4 Note the "empty position".
5 Switch air supply on. Note full position again. Check that it correlates with No.1.
6 Check, with the air supply turned fully on, that the diver is able to breathe through both 2nd stages (if an octopus is fitted).
7 Check that breathing does not cause oscillation of the pressure gauge needle. If it does then the air supply should be checked to be certain that it is turned fully on.
8 Check that there is no positional free flowing of either second stage.
9 If the contents gauge is bumped before getting into the water, these checks should be performed again.
10 Check that the diver knows where his or her regulators are (especially the octopus).
11 Once in the water, do a surface check on any positional free flowing of the regulators.

SONIC RESERVE

Regulator manufacturers should be encouraged to reintroduce the sonic reserve and divers should be encouraged to buy this excellent safety device.

OXYGEN AND ADMINISTRATION

Australia wide standards for courses on oxygen therapy and equipment applicable to diving accidents should be developed.

ALTERNATIVE AIR SUPPLY

There are many alternative air sources available. They should have minimum standards of performance. The commonest is the octopus regulator. However this usually needed when both divers are low on air. In this situation the 1st stage regulator may not be able to provide enough flow to supply both regulators at once. Neither may it be able to supply enough air to inflate the owner's buoyancy compensator.

If a separate cylinder is used (Spare Air etc.) should this air source be able to supply the buoyancy jacket to give buoyancy as well?

TRAINING

There should be more emphasis in diving training on shared breathing and equalization techniques.

There should be better teaching and understanding of the dive tables.

Crisis management algorithms should be developed for the out-of-air situation, and for the First Aid management of diving accidents.

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EMERGENCY AIR SHARING

Glen Egstrom

Introduction

The purpose of this paper is to focus upon a positive approach to the standardisation of an important emergency procedure, sharing air. The behavioural aspect of this procedure could be effectively standardised with a minimum modification of equipment and existing techniques.

Why share air ?

Other than in training classes, one is normally only going to have to share air when one's buddy is out-of-air. It is a time of considerable stress. An out-of-air situation is most unlikely for a scuba diver who monitors his or her air supply. It can happen, but it is rare.

In many parts of the world regulators freeze. When gas expands it tends to cool. Air is expanding when it comes through the low pressure hose. We have tested a series of regulators at various temperatures and at various depths. Virtually all the regulators on the market will freeze up if they get cold enough and have enough air going through the regulator. Typically the regulator valve will stay in the open position, a free flow, and with free flow you get a tremendous cooling effect causing ice to form on the outside and on the inside of the regulator. Sometimes the regulator will freeze shut. This is a difficult and serious problem. In between sheet ice actually forms on the diaphragm increasing the breathing resistance. The increase in breathing resistance is enough to create additional stress as the diver may feel that he is out-of-air. Every regulator available is going to be more difficult to breathe from at low tank pressure and at depth.

A tropical diving holiday is probably the worst possible environment for a scuba diver. It takes about 72 hours to get about 80% acclimatised. Divers rarely have that long before they go to work enjoying themselves. Inspite of understanding the problem, we consistently let ourselves become dehydrated during the first two or three days. We are not sensitive to the need to push fluids when we arrive in the tropics. In addition we are offered deep, clear, warm water, party times and late nights. We are not as well prepared for some of our dives as we should be. As a result mistakes are made.

Many people who encounter increased breathing resistance interpret that as an out-of-air situation. It is important that people recognise that if one breathes slower and so keeps the peak flow rates low, then the resistance is going to be lower and one will be able to get air out of the tank comfortably for much longer. In most of the regulators on the market excessive breathing resistance starts about 500 or 600 psi tank pressure at depths of 20 m or more. Most of the good regulators on the market have different characteristics because the balanced first stages are so finely tuned that they