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South Pacific Underwater Medicine Society

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To provide information on underwater and hyperbaric medicine.
To publish a journal.
To convene members of the Society annually at a scientific conference.

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1 Anderson T, RAN medical officers' training in underwater medicine. *SPUMS J* 1985; 15: (2) 19-22
2 Lippmann J, Bugg S. The diving emergency handbook. Melbourne: J.L.Publications, 1985

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EDITORIAL

Richard Dawkins in his book "The Selfish Gene" has highlighted a very real and everlasting conflict of interest between actions which are of immediate and apparently obvious advantage to the individual as contrasted with those which limit the individual but benefit the group of which he/she is a member in either the short term or the long run. Such a conflict is present in any consideration of the competing arguments concerning whether buddy diving is a mode of diving advantageous to the individual diver. Although this is a major shibboleth which diving instructors indoctrinate into their pupils it is certainly a rule of conduct poorly practiced by many "real divers". This is possibly a reflection of their belief that accidents only happen to others, that any buddy would be an encumberance they would have to shepherd around and end up having to rescue. Two papers in this issue bear directly on this matter and may induce readers to give some thought to the value and practicality of actually buddy diving.

There is no doubt, as Bob Halstead states, that many divers de facto dive safely and regularly in the solo mode, "hanging out with Halo Jones" as a pop song describes the all-alone state. Their dives are usually free from significant incident. Usually. Against this must be placed the undoubted fact that the majority of diving fatalities occur when the diver is alone, either because they were solo diving or following separation. Solo diving can be regarded as akin to driving in the outback without a spare wheel and can of fuel, or going out to sea without a radio and life support equipment. Both are usually safe. There is in some persons' minds a misunderstanding of both the desired end point in diver training and the reason for following a buddy-diving technique. Courses of instruction are intended to produce safe divers, people able to care for themselves and provide assistance to their buddy. They are <u>not</u> being trained to rely on others but to trade off loss of some independence against the "insurance" of having available a source of psychological and physical support in time of need if such should occur. As with insurance, there are good and shonky providers and the wise diver chooses to assess his companion to ensure that they can both manage the proposed dive conditions. The case report extends the concept of buddy responsibility somewhat so that it merges into the biblical concept of responsibility to one's neighbour, a concept which hopefully more than the biblical scholars among our readers will recognise. In this case the final adverse factor was the separation of the two divers and this undoubtedly influenced the outcome. It may be argued that only inexperienced divers and those who are undergoing training require to practice such discipline, that experienced divers never get into such difficult situations. Such a belief can be lethal. And to those who reply "Well, it's my life" the group answer might be "True, but your death or decompression sickness will reflect badly on the diving community".

Many readers may prefer to avoid the self analysis involved in questioning their diving techniques and first read the papers on drugs and diving and women in diving, unrelated but equally important matters. There is some cross-over relevance with the paper by Marcus Skinner on the hypobaric chamber used to teach pilots and others the symptoms of sudden reduction in ambient pressure (and oxygen level). It was in such a chamber test facility in the USA that the suggestion was first made that women were both more likely to suffer decompression sickness as a result of such "altitude" exposure and are most resistant to treatment. This fact should be an indication of our limited understanding of decompression sickness pathology. As decompression sickness can arise using "safe" decompression stresses, divers may consider that there is great virtue in obeying the no-flying-after-diving warnings they have undoubtedly heard about and read in their text books.

Fairy stories tend to end with the comfortable words "and they lived happily ever after" and many divers show a tendency to believe that if they suffer symptoms of decompression sickness their story will end "so they took him/her to the recompression chamber and he/she was cured". While this may well be true in most instances the paper by Andrew Peacock and Ray Palmer is a timely reminder that there is rather more to operating a chamber successfully than turning a few valves. Chambers may be regarded, like most mechanical devices, as "ornery critters" which require careful attendance or they will subject their customers to unsatisfactory and undesirable conditions. Their analysis of some of the problems of chambers is timely in these days when they are apt to be regarded as a panacea, a piece of furniture no diving area should be without. Perhaps this is just one more reason for avoiding all risk of contracting decompression sickness.

The papers reprinted from Undercurrent discuss dive computers from the purchaser's point of view. Though these computers make diving easier they do not guarantee avoiding decompression sickness and they have their mechanical problems.

Finally Ted Egan's moving song of the death of a diver from a pearling lugger makes his record worth buying for it alone regardless of what else is on the record. Egan's songs are, like this one, full of compassion and love for all the people of outback Australia.

ORIGINAL ARTICLES

CARBON DIOXIDE AND HUMIDITY CONTROL IN A HYPERBARIC CHAMBER

Andrew Peacock and Ray Palmer

Introduction

There is a hyperbaric chamber located at the Australian Institute of Marine Science (AIMS) which is 50 kilometres by road south of the coastal city of Townsville in North Queensland. It is a multiplace hyperbaric treatment facility with two locks that can be independently pressurised. The term recompression chamber (RCC) is commonly applied to such a facility as it is used to compress divers as part of a therapeutic regimen[1]. The RCC at AIMS is supported medically by the Intensive Care Unit at the Townsville General Hospital. It was established in 1977 and since then has been used almost exclusively for the treatment of divers with hyperbaric illness. Only nine patients with illnesses unrelated to diving have been treated in the RCC. From the beginning of 1986 to the time of writing, sixty-nine divers had undergone therapeutic recompressions for cerebral arterial gas embolism (CAGE) and/or decompression sickness (DCS). Of these, twenty-four had required retrieval to the AIMS RCC using the Drager Duocom, a transportable two-man RCC, which was operated out of Townsville by the National Safety Council of Australia (Victorian Division).

As part of its requirement to meet the therapeutic needs of critically-ill patients with either cerebral arterial gas embolism or decompression sickness, the operators of a recompression chamber must be able to:

1. Measure and maintain the levels of oxygen and carbon dioxide.
2. Measure and maintain at tolerable levels humidity within the RCC.

It is important to measure the performance of a RCC with regard to these requirements. However such performance testing has not been carried out on the RCC at AIMS. This study was carried out to assess the performance of the carbon dioxide elimination, humidity control and oxygen make-up systems which can be fitted to the RCC at AIMS. The study was conducted without personnel inside the RCC.

The AIMS RCC has two compartments, an air lock or outer chamber (volume = 3,250 dm^3) and a treatment or main chamber (volume = 7,600 dm^3). The compartments are separated by a pressure locking door. Five trials were conducted, a carbon dioxide absorption trial in each chamber, a carbon dioxide-humidity trial in each chamber and an oxygen make-up trial in the main chamber.

All pressures are given as bars absolute. Although not strictly a SI unit, this unit has been used because of the ease of conversion from water depth to bar. Each 10 msw increment in depth equals an increase in pressure of 1 bar (1 bar = 1 atmosphere).

Carbon dioxide absorption trials

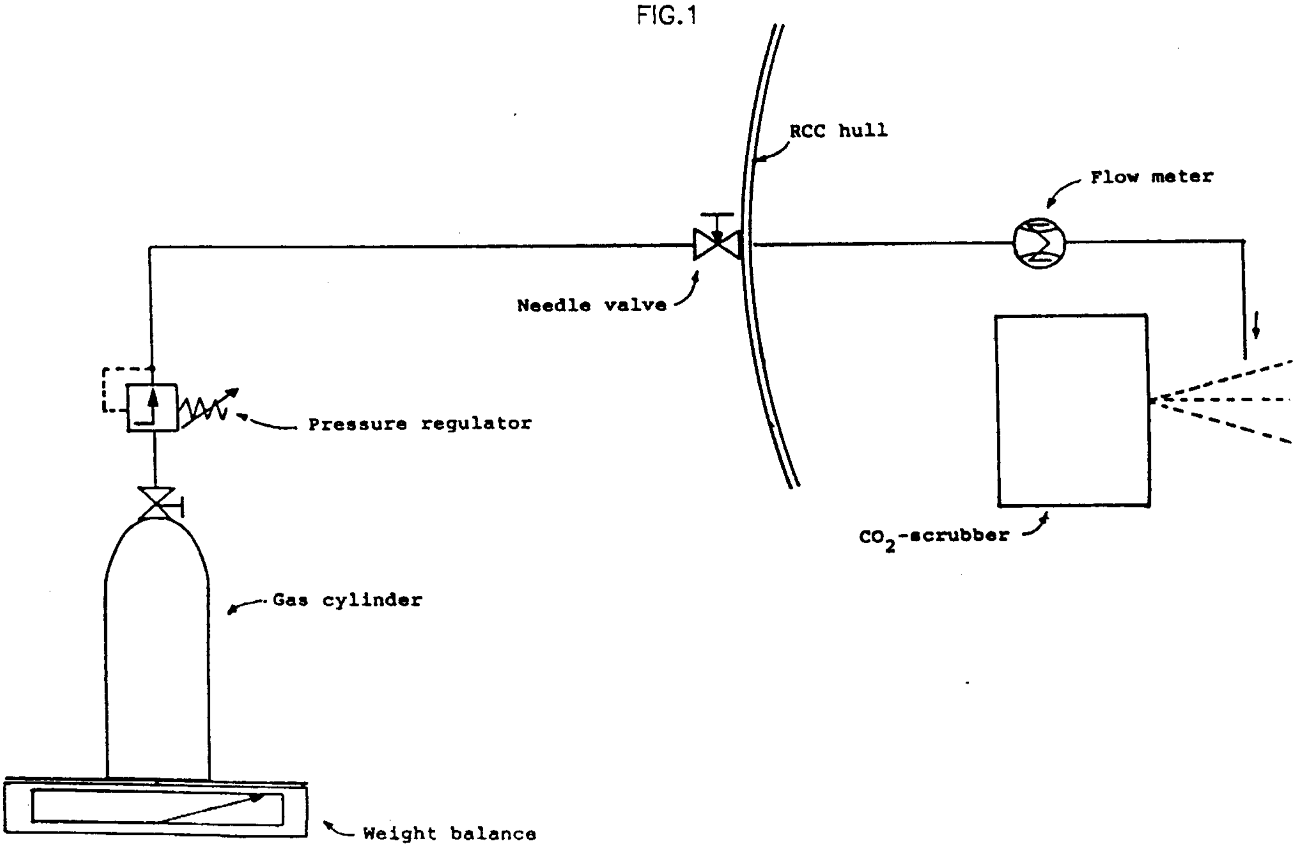
Carbon dioxide is normally present in the atmosphere in a concentration of 0.03 to 0.04% volume of dry air. Carbon dioxide is a product of metabolism which can have toxic effects. The production of carbon dioxide can vary from 200 ml carbon dioxide STPD/min for an individual at rest to 6000 ml carbon dioxide STPD/min during extreme work.

Hypercapnia is an abnormal elevation of carbon dioxide levels in the body. The patho-physiological changes associated with hypercapnia are called carbon dioxide toxicity. Two situations in the enclosed environment of a hyperbaric chamber can lead to carbon dioxide toxicity in the chamber occupants, inadequate ventilation of the RCC where flushing is required to remove carbon dioxide or failure of a carbon dioxide absorber system[1]. An increase in the partial pressure of carbon dioxide (PCO_2) in a RCC is much more likely when the chamber occupants are active and producing large amounts of carbon dioxide.

Observable responses to raised ambient carbon dioxide levels begin with increases in the depth and rate of respiration at between 10 and 20 millibars[1]. The maximum permissible concentration (MPC) of carbon dioxide varies with exposure-time. Given that therapeutic recompressions take several hours, the appropriate MPC for PCO_2 for hyperbaric treatment exposures in a RCC is 10 millibars. It follows that the level of carbon dioxide should be maintained at less than 10 millibars[2]. Using a molecular weight of 44 for carbon dioxide and knowing that under standard conditions one mole of gas occupies 22.4 litres, carbon dioxide production rates in litres per minute can be translated to production rates in grams per minute (g carbon dioxide/min). A therapeutic RCC must be able to remove the carbon dioxide products of 3 moderately exercising individuals (a patient convulsing and 2 attendants). That is a carbon dioxide production rate of approximately 5.3 to 5.9 g carbon dioxide/min (900 ml carbon dioxide STPD/min to 1,000 ml carbon dioxide STPD/min). The situation described above would represent an extreme load on the carbon dioxide removal system for the main chamber of a RCC. During a therapeutic recompression in the main chamber the outer chamber may be required to transfer a person from outside the RCC into the main chamber. Consequently a carbon dioxide production rate of approximately 3.0 g carbon dioxide/min would represent an extreme test of the carbon dioxide removal capability of the outer chamber.

The RCC at AIMS has two means by which the operators can reduce the carbon dioxide concentration gen-

FIG.1



erated by the occupants. In each of the main and outer chambers there is an electrically powered carbon dioxide scrubber which uses a blower to force chamber gas through a cannister containing a granulated carbon dioxide absorbing agent (Sodasorb).

The chamber operator of the RCC at AIMS can also remove carbon dioxide by ventilating the chamber with air. This is done while maintaining the chamber ambient pressure constant. Ventilation is performed by opening both the pressurisation and the exhaust valves at the same time. There should be no requirement for this if the carbon dioxide scrubber system is working efficiently.

AIM OF THE STUDY

To evaluate the performance of the carbon dioxide absorbing systems in the main and outer chambers of the RCC.

METHODS

Two separate trials were conducted, one in each of the chambers. In each trial, carbon dioxide was added to the RCC environment at a known rate, using the equipment as shown in Figure 1. The carbon dioxide-scrubber outlet flow was used to distribute the carbon dioxide around the RCC. A cylinder of carbon dioxide was connected through a pressure regulator (adjusted to give a line pressure of 8.0 bar) and a needle valve to the chamber via a flexible hose. The rate at which carbon dioxide was added to the RCC was monitored by placing the cylinder on an electronic weight balance (Digi Model 430) (weight loss/time = rate of addition of carbon dioxide in grams). The weight balance was calibrated using standard weights prior to use. The scale was in 5 gram increments.

The needle valve was used to adjust the rate of carbon dioxide addition. This could be monitored by observation of a CIG flow meter placed inside the RCC. The carbon dioxide passed through this before being released from flexible tubing positioned above the carbon dioxide scrubber outlet. The needle valve was continually adjusted to maintain a carbon dioxide addition rate of: between 5.3 and 5.9 g carbon dioxide/min for the main chamber trial and 3.0 g carbon dioxide/min for the outer chamber trial.

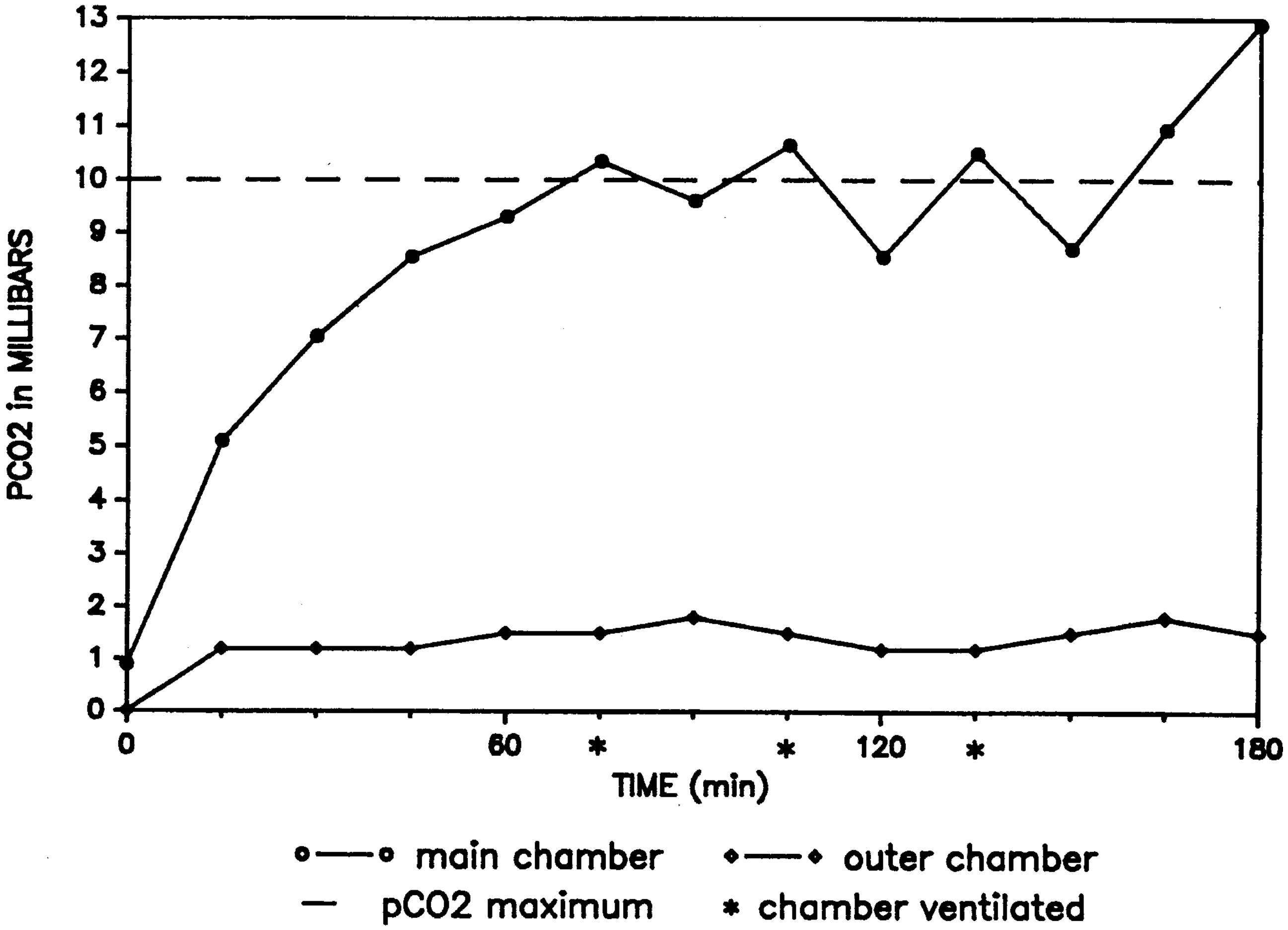
The actual carbon dioxide addition rates were main chamber 5.94 g carbon dioxide/min and outer chamber 2.92 g carbon dioxide/min

With the carbon dioxide scrubber operating in the RCC compartment being tested, carbon dioxide was added to the compartment for 180 minutes while the internal compartment pressure was maintained at 6 bars absolute. This pressure was chosen because this is the greatest pressure used to treat dysbaric illness[2,3]. The PCO_2 was measured every 15 minutes during this period, by withdrawing gas from the RCC, and using an Infrared carbon dioxide analyser (GasTech Model RI-411). This analyser was precalibrated

FIG.2

CARBON DIOXIDE ABSORPTION TRIAL

BOTH CHAMBERS



according to standard operating manual procedures. The analyser provided a continuous digital display of instantaneous carbon dioxide concentration to the nearest 50 ppm. Its output (ppm) was converted to millibars (ppm carbon dioxide/1000 x Pamb).

RESULTS

The PCO_2 data were corrected for the actual carbon dioxide addition rates (main chamber trial 6/5.94, outer chamber trial 3/2.92) and are listed in Table 1 and displayed in Figure 2.

DISCUSSION

Although the carbon dioxide addition rates used for the trials reflected moderate exercise only, the duration of these exposures makes the trials an extreme test of the RCC's carbon dioxide absorption system as this level of exercise would not be maintained for over 180 minutes.

The data show a marked difference between the capabilities of the carbon dioxide absorbing systems in each compartment of the RCC. While the PCO_2 in the outer chamber remained at a level significantly less than 10 millibars for the duration of the trial, the PCO_2 in the main chamber reached this accepted upper limit between 60 and 75 minutes.

At 75 minutes it was decided to ventilate the main chamber in an attempt to decrease the PCO_2. The first ventilation involved exchanging approximately 10 m^3 of air (over 90 seconds) and it decreased the PCO_2 from 10.35 millibars to 7.8 millibars at the end of that 90 seconds. However within 15 minutes the PCO_2 had increased to 9.6 millibars and then again exceeded the 10 millibar exposure limit. The chamber was subsequently ventilated at 105 minutes and again at 135 minutes (approximately 38 m^3 and 29 m^3 of air respectively). These ventilation periods also proved ineffective in decreasing the PCO_2 appreciably for any length of time.

In contrast, the performance of the carbon dioxide scrubber in the outer chamber is certainly adequate.

The performance of the main chamber carbon dioxide scrubber is unacceptable. In the latter stages of the trial, despite repeated chamber ventilation the PCO_2 continues to

TABLE 1

CARBON DIOXIDE ABSORPTION TRIAL

MAIN AND OUTER CHAMBERS

CARBON DIOXIDE LEVELS IN MILLIBARS

Time (minutes)	Main Chamber	Outer Chamber
0	0.90	0
15	5.10	1.20
30	7.05	1.20
45	8.55	1.20
60	9.30	1.50
75	10.35*	1.50
90	9.60	1.80
105	10.65*	1.50
120	8.55	1.20
135	10.50*	1.20
150	8.70	1.50
165	10.95	1.80
180	12.90	1.50

* Chamber ventilated

CO_2 addition rates

Main chamber 6/5.94 gCO2/min
Outer chamber 3/2.92 gCO_2/min

rise steeply (Figure 2). This indicates that the Sodasorb granules are no longer efficiently absorbing carbon dioxide, i.e. their capacity has been exceeded. During a recompression where there is such extreme carbon dioxide production they would therefore need to be replaced regularly. Fresh Sodasorb can be transferred to the main chamber via the outer chamber. Continuous ventilation of the chamber will be needed when replacing the carbon dioxide absorbent. This places a demand on the high pressure air supply to the chamber and hinders communication between the RCC operator and occupants because of the associated noise.

The basic problem was that the air flow rate of the carbon dioxide scrubber unit in the main chamber was too low. The cause of this has since been found to be a faulty electrical terminal connected to the carbon dioxide scrubber.

Carbon Dioxide and Humidity Trials

Humidity is of importance in a RCC primarily because of the narrowed humidity and thermal comfort zone that exists under hyperbaric conditions for the patient and the in-chamber attendant(s)[3]. Humidity is a particular problem in the RCC at AIMS where ambient relative humidity during the summer months (in the non-airconditioned building containing the RCC) often remains close to 100%. This makes a therapeutic recompression in the RCC very uncomfortable.

A high level of water vapour pressure in the air reduces the effectiveness of the sweating mechanism for cooling the body by evaporation. This results in increased sweating which will increase the often already dehydrated state of the patient suffering from DCS. A high level of humidity places a thermoregulatory stress on the body which is undesirable for both the patient and the attendants in the RCC.

Desirable relative humidity within the confines of a RCC being used for hyperbaric oxygen therapy is in the range 50% to 75%[3].

One approach for humidity control in a RCC is to use a moisture absorbent (desiccant) such as silica gel which can be regenerated. This can be used in a scrubber system equivalent to those used for removal of carbon dioxide and often may be contained in the same container. The RCC at AIMS has no such scrubber system in operation. Instead, to keep relative humidity within the chamber at a reasonable level, the chamber operator intermittently ventilates (or flushes) the RCC with air from the high pressure air bank which contains less water vapour than the chamber air. In the summer months this may need to be done as often as once every 5 to 10 minutes. Although it is not difficult to ventilate the chamber, the necessity to monitor the humidity within the RCC constantly and ventilate the chamber places extra demands on the chamber operator. Equally as important is the observation that the process of ventilating the RCC produces a level of noise (> 90 dB) within the chamber which can be disconcerting to both the patient and the in-chamber attendant(s), especially when ventilation is occurring frequently. Also the noise from ventilation makes any communication between chamber occupants and the RCC operator difficult.

The carbon dioxide scrubber used in the RCC functions by causing an air flow over sodalime, an alkali metal hydroxide reagent (Sodasorb). The chemical reactions involved are as follows[1]:

$$H_2O + \text{carbon dioxide} \rightarrow H_2CO_3$$
$$H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$$
$$Na_2CO_3 + Ca(OH)_2 \rightarrow 2NaOH + CaCO_3$$

These reactions produce one molecule of water for each molecule of carbon dioxide removed. Hence they contribute significantly to an increase in the humidity of the

TABLE 2

CARBON DIOXIDE HUMIDITY TRIAL

MAIN CHAMBER CARBON DIOXIDE LEVELS IN MILLIBARS

WITH AND WITHOUT DESICCANT

Time (minutes)	No desiccant	With desiccant
0	1.20	1.20
5	1.80	3.75
10	2.70	5.70
15	5.10	8.10
20	6.30	9.90
25	7.20	11.40
30	8.10	12.45
35	8.55	
40	9.15	
45	9.60	
50	10.20	
55	10.50	
60	10.80	

TABLE 3

CARBON DIOXIDE HUMIDITY TRIAL

HUMIDITY IN THE MAIN CHAMBER WITH AND WITHOUT DESICCANT

(Expressed as percent relative humidity)

Time (minutes)	No desiccant	With desiccant
0	58.0	54.0
5	63.0	55.0
10	67.5	54.0
15	71.0	52.0
20	74.0	50.0
25	77.0	49.0
30	79.0	48.0
35	81.5	
40	83.0	
45	85.0	
50	86.5	
55	88.0	
60	89.5	

CO_2 addition rates

No desiccant 5.5/5.50 gC02/min
with desiccant 5.5/5.67 gCO_2/min

RCC environment that occurs during a therapeutic recompression. It follows that the carbon dioxide scrubber system can be used to test the humidity control system of the RCC.

AIM OF STUDY

To evaluate the performance of a desiccant granule humidity control system in the main and outer chambers of the RCC.

METHODS

Two separate trials were conducted, one in each chamber of the RCC. In each trial, carbon dioxide was added to the RCC environment at a known rate using the equipment set up as previously described for the carbon dioxide Absorption Trial (Figure 1). The trial was performed in each chamber under two different conditions. First with desiccant granules (silica gel) in a three litre cannister that was fitted to the outlet of the carbon dioxide scrubber in that chamber and then with no desiccant granules. The desiccant granule cannister was specifically designed for the trial by staff in the AIMS workshop.

With the carbon dioxide scrubber operating in the RCC compartment being tested, carbon dioxide was added to the compartment for 1 hour at a rate similar to that used for the carbon dioxide Absorption Trial while the internal ambient compartment pressure was maintained at 6 bars absolute. The carbon dioxide addition rates were as follows:

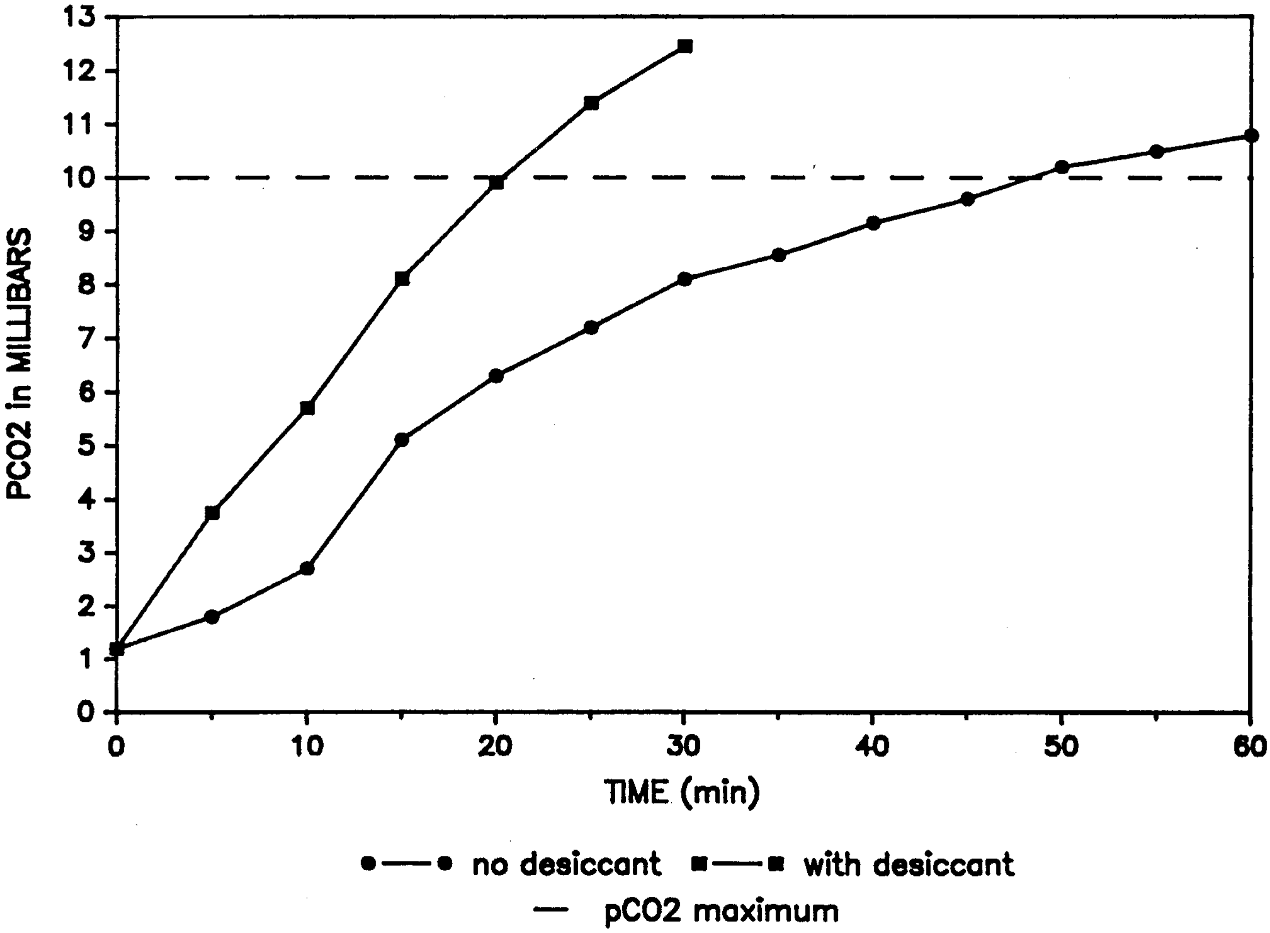
Main Chamber
No desiccant 5.50 g carbon dioxide/minute
With desiccant 5.67 g carbon dioxide/minute
Outer Chamber
No desiccant 3.00 g carbon dioxide/minute
With desiccant 3.08 g carbon dioxide/minute

The PCO_2 was measured every 5 minutes during this

FIG.3

CARBON DIOXIDE–HUMIDITY TRIAL

MAIN CHAMBER



period using a pre-calibrated Infrared carbon dioxide analyzer (GasTech model RI-411). The relative humidity inside the chamber was measured directly every 5 minutes using a hair hygrometer (Measuretec) which had previously been calibrated. It recorded in one percent graduations. This instrument was mounted inside the chamber so that it could be viewed easily from the outside through one of the chamber portholes.

RESULTS

The PCO_2 data (corrected for the actual carbon dioxide addition rates) and relative humidity data for the main chamber trial are listed in Tables 2 and 3 and displayed in Figures 3 and 4. The data for the outer chamber trial are listed in Tables 4 and 5 and displayed in Figures 5 and 6.

DISCUSSION

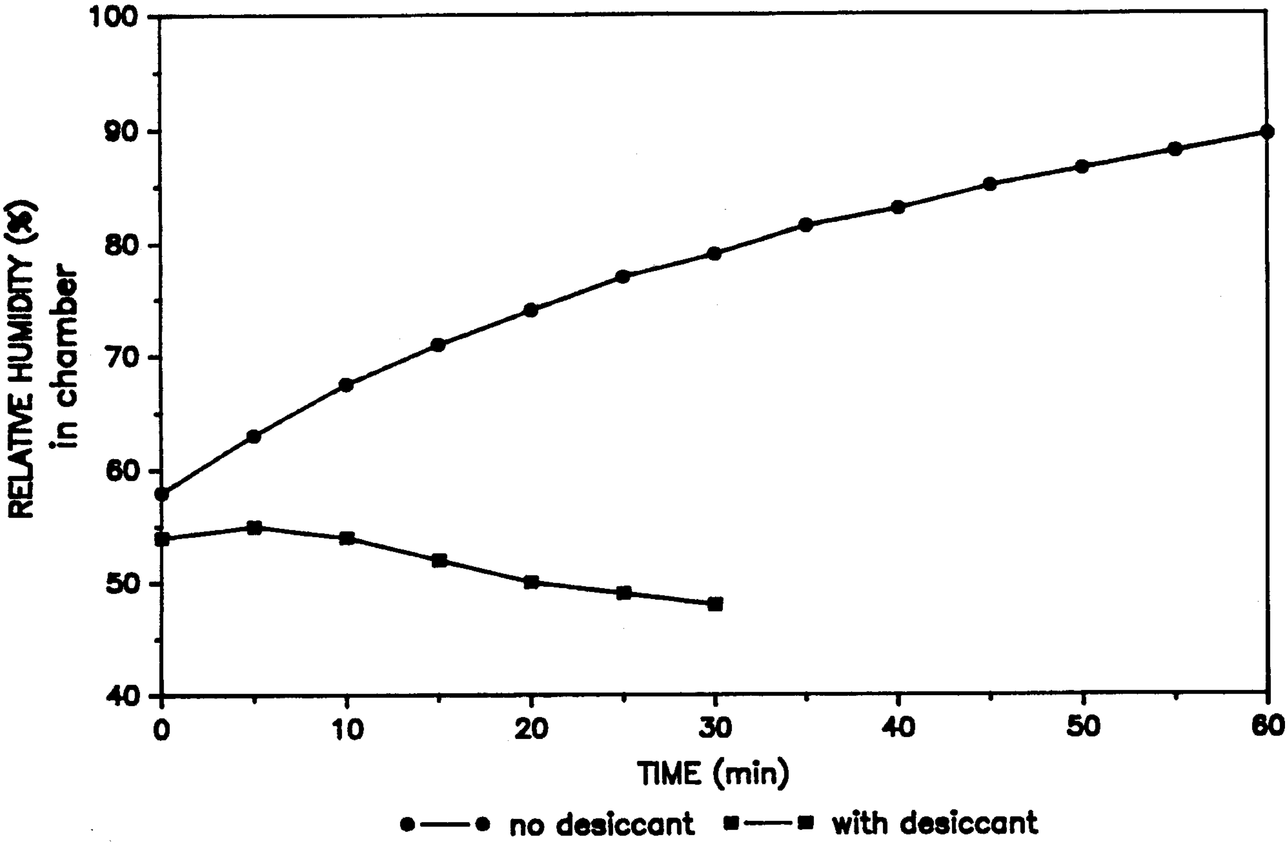
The PCO_2 data once again showed that the carbon dioxide scrubbing system operating in the main chamber was much less efficient than that in the outer chamber (Figures 3 and 5). In both chambers the PCO_2 was higher over the 60 minute period when desiccant granules were present. However, there was a much greater effect in the main chamber trial. After 20 minutes the PCO_2 had reached the 10 millibar exposure limit in the main chamber when desiccant granules were in the cannister compared to between 45 and 50 minutes when there was no silica gel present. In fact, the addition of carbon dioxide was halted after only 30 minutes when silica gel was present because at this time the PCO_2 measured 12.45 millibars which is well above the acceptable limit and hence made further carbon dioxide addition under those conditions unnecessary for the purposes of the trial. In contrast however the PCO_2 for both conditions in the outer chamber trial remained well below 10 millibars, reaching a maximum of 4.05 millibars when silica gel was present.

For both trials the relative humidity was much higher when there was no desiccant present to remove moisture from the chamber air (Figures 4 and 6). This was especially so for the outer chamber when the relative humidity reached 90% after only 20 minutes. These changes in relative humidity when no desiccant was present within the chamber can be compared with the changes in relative humidity

FIG.4

CARBON DIOXIDE–HUMIDITY TRIAL

MAIN CHAMBER



outside the chamber which were only of the order of 3% during the main chamber trial and 1% during the outer chamber trial.

The trial has shown that the cannister of silica gel attached to the carbon dioxide scrubber outlet will control the arbitrarily chosen high level of humidity generated by the carbon dioxide scrubber. This is true for both chambers of the RCC. It is important to note however that the duration of the trials was only sixty minutes and as therapeutic recompressions can take at least five hours to complete, it is possible that the moisture absorbing capacity of the 3 kilograms of silica gel used in each trial would have been exceeded within this time. This would require that fresh silica gel be placed in the cannister before the previous supply became saturated with water.

The major problem with this system for controlling humidity is that the silica gel was impairing the function of the carbon dioxide scrubber (Figures 3 and 5). This was probably because of the increased resistance to airflow produced by the desiccant granules as air passed from the carbon dioxide scrubber into the desiccant granule cannister and then out into the chamber. This increased airflow resistance severely compromised the function of the carbon dioxide scrubber in the main chamber. This was to be expected considering there was already a low flow rate through this carbon dioxide scrubber because of an electrical fault. However, only a small effect was noted in the outer chamber where carbon dioxide levels were raised by a maximum of 2.55 millibars but remained well below the MPC for carbon dioxide.

Oxygen make-up trial

The critical life-support variable in a RCC is oxygen. Control of oxygen involves both analysis and restoration of PO_2 to the required level (make-up). The proper level of oxygen to be maintained in the chamber is a function of the duration of the exposure, and it may range between a low of approximately 0.21 bars to as great as 1.6 bars[3]. It is important to remember that the significant factor with regard to toxicity is oxygen partial pressure and not concentration[4].

When conventional therapies do not resolve the symptoms and signs of either decompression sickness or cerebral arterial gas embolism, it may occasionally be necessary to use an air saturation therapy. Because such therapy involves exposures longer than 4 hours the PO_2 cannot exceed 0.6 bars (the pulmonary oxygen toxicity limit). Since there is metabolic consumption of oxygen by the RCC occupants the PO_2 will fall within the RCC. It follows that

TABLE 4

CARBON DIOXIDE HUMIDITY TRIAL

OUTER CHAMBER CARBON DIOXIDE LEVELS WITH AND WITHOUT DESICCANT

PCO2 in millibars

Time (minutes)	No Desiccant	With Desiccant
0	0	0
5	0.90	0.90
10	1.20	2.40
15	1.20	2.85
20	1.20	2.85
25	1.20	3.45
30	1.20	3.45
35	1.20	3.75
40	1.50	4.05
45	1.50	4.05
50	1.50	4.05
55	1.50	3.75
60	1.50	3.75

CO_2 addition rates

no desiccant 3/3.00 gC02/min

with desiccant 3/3.08 $gC0_2$/min

TABLE 5

CARBON DIOXIDE HUMIDITY TRIAL

OUTER CHAMBER HUMIDITY WITH AND WITHOUT DESICCANT

(Expressed as percent relative humidity)

Time (minutes)	No Desiccant	With Desiccant
0	42.0	46.0
5	62.0	44.0
10	78.0	41.0
15	87.0	39.0
20	90.5	37.0
25	92.0	37.0
30	93.0	36.5
35	94.0	36.5
40	95.0	36.5
45	95.5	37.0
50	96.0	37.0
55	96.0	38.0
60	96.5	39.0

the oxygen levels must be carefully monitored and maintained. A commonly used technique to add oxygen to the RCC, in the absence of a dedicated oxygen make-up system, is to allow the built in breathing system (BIBS) for oxygen to free flow.

The consumption of oxygen is exercise dependent, varying from 250 ml oxygen STPD/min for an individual at rest to possibly 5,000 ml oxygen STPD/min during extreme work (depending on the size and physical fitness of the individual). A therapeutic RCC needs to be able to match the oxygen needs of 3 moderately exercising individuals (a patient convulsing and 2 attendants), which is an oxygen consumption rate of about 3,000 ml oxygen STPD/min. The main chamber volume of the RCC at AIMS is 7,600 dm^3, therefore an oxygen consumption of 180 dm^3/hour will decrease the oxygen concentration in the main chamber to approximately 18.5% after one hour. This represents a decrease in PO_2 from 585 millibars to 518 millibars when the chamber is pressurised on air to 2.8 bars. The RCC operator would therefore need to increase the PO_2 in the main chamber by an hourly increment of around 65 millibars to compensate for this level of oxygen consumption by the RCC occupants (an oxygen make-up). This will ensure that the PO_2 remains at the highest safe level possible in the RCC in order to minimise the amount of inert gas (nitrogen) present while the patient is breathing air.

AIM OF STUDY

To develop a standard technique for oxygen make-up of 50 to 60 millibars in the main chamber of the RCC.

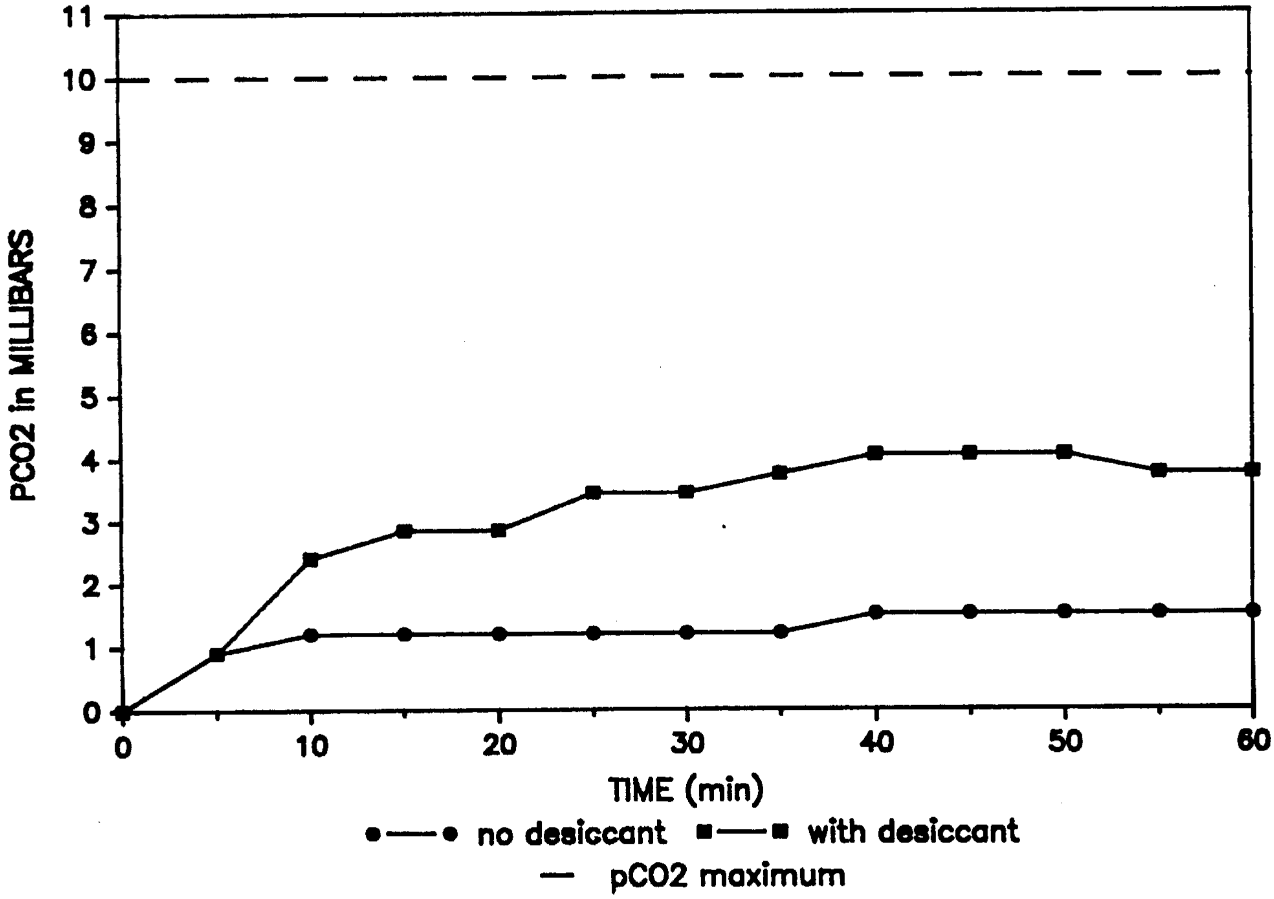
METHODS

An oxygen make-up trial was conducted in the main chamber of the RCC at a pressure within the chamber of 2.8

FIG.5

CARBON DIOXIDE–HUMIDITY TRIAL

OUTER CHAMBER



bars absolute (the pressure chosen for an air-saturation therapy). The main chamber was flushed with nitrogen to reduce the PO_2 (to around 500 millibars). A needle valve outside the chamber was turned on to allow the BIBS input line to free flow for a variable amount of time. The oxygen level within the main chamber was monitored continuously by drawing air from the chamber and passing the stream through a galvanic cell sensor (placed in a T-piece adaptor) of a precalibrated oxygen monitor (Hudson Model 5550).

This monitor has an analog galvanometer needle which shows oxygen concentration in 1% graduations: a small portable voltmeter (Fluke Model 8022A Multimeter) was connected to the monitor which enabled its output to be recorded in 0.1% graduations.

Atmospheric air and gases of known concentration as determined from Lloyd-Haldane analysis were used to assess the accuracy of this oxygen analysis system throughout the expected range of measurement. It was found that the voltmeter reading provided an accurate means by which the oxygen concentration in the RCC could be determined. The percent reading of the oxygen analysis system was converted to PO_2 in millibars (% oxygen x Pamb x 10).

At the beginning of each oxygen make-up a starting PO_2 reading was taken before the valve was opened. A second PO_2 reading was then taken two minutes after the valve was shut off. Following this the chamber was again flushed with nitrogen to return the PO_2 to approximately 500 millibars. This procedure was performed 7 times.

RESULTS

The first oxygen make-up increased the PO_2 by 30 millibars. On the second oxygen make-up it was found that turning the valve one full turn and leaving it open for 40 seconds raised the PO_2 by 56 millibars. This exact regimen was repeated another five times, the PO_2 on each occasion rising by either 56 or 59 millibars i.e. a change in oxygen concentration of 2.0 or 2.1%.

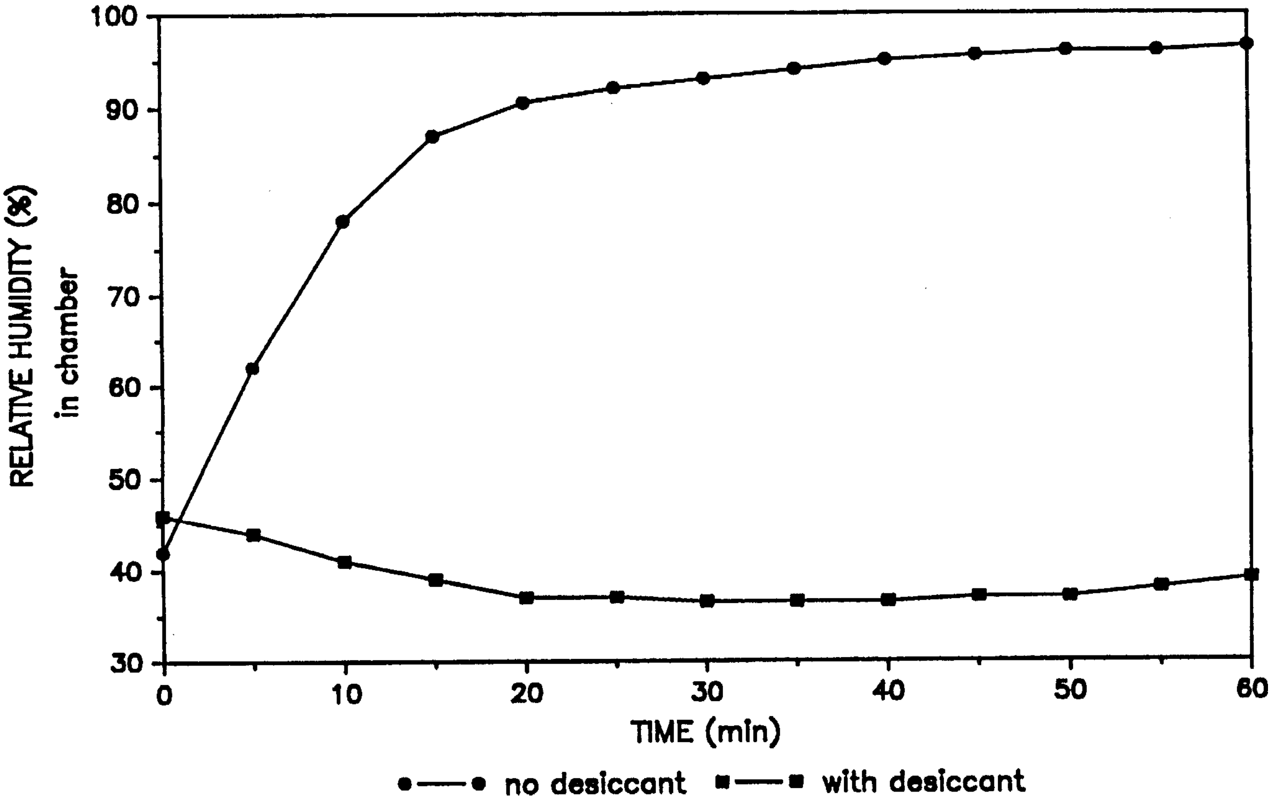
DISCUSSION

It was discovered that a 40 second period of opening the oxygen make-up valve one full turn reliably and predictably raised the PO_2 by 56 to 59 millibars. This technique is recommended as a simple and reliable method of raising the PO_2 in the chamber...

FIG.6

CARBON DIOXIDE–HUMIDITY TRIAL

OUTER CHAMBER



During each oxygen make-up when oxygen was added to the RCC environment, the percentage oxygen reading of the analyser increased by 8 to 10% initially. The reading then decreased over 1 to 1 1/2 minutes before stabilising. This artefact was caused by the proximity within the chamber of the oxygen make-up input and the oxygen analyser pick-up valve; an arrangement which needs to be changed.

Summary

The trials carried out on the RCC at AIMS discovered inadequacies associated with the control of carbon dioxide and humidity levels within the main chamber of the RCC.

The carbon dioxide absorbent system in the main chamber was not functioning properly. It could not maintain a PCO_2 level of less than 10 millibars when subjected to extreme conditions of carbon dioxide production. This unsatisfactory situation in the main chamber was due to an inadequate air flow through its carbon dioxide scrubber. This was due to a faulty electrical terminal connected to the carbon dioxide scrubber.

The humidity control system tested in the RCC prevented the rise in humidity that took place when no such system was fitted to the RCC. However, it decreased the ability of the carbon dioxide scrubber units to remove carbon dioxide from the chamber atmosphere. This was especially evident in the main chamber where function of the carbon dioxide scrubber was already inadequate.

The oxygen make-up trial found a reliable technique by which the PO_2 in the main chamber could be predictably increased by the required 56 to 59 millibars.

Conclusions and recommendations

The faulty electrical terminal causing the poor function of the carbon dioxide scrubber in the main chamber needs to be repaired. Once this has been done the carbon dioxide absorption trial should be repeated in the main chamber over a period of 5 hours to determine if the PCO_2 in the chamber can be kept below 10 millibars for this duration of carbon dioxide production.

A further trial should be conducted on the main chamber with a view to developing an effective humidity control system. It should be conducted in the same manner as the carbon dioxide humidity trial previously outlined but with three important differences. The carbon dioxide scrubber needs to be fully operational. A larger desiccant granule cannister (4 or 5 litres) should be used. The trial should last for a period of 5 hours (based on RN Table 62). It would only remain then to test the desiccant granule cannister system while a therapeutic recompression is taking place. The aim should be to develop a system that keeps the relative humidity in the main chamber at less than 75% and does not allow the PCO_2 to reach 10 millibars.

The outer chamber carbon dioxide and humidity control systems are functioning adequately and need no further testing.

The need for air saturation therapy of DCS and/or CAGE is rare. However, the oxygen make-up trial has provided information that will prove useful to the operators of the RCC at AIMS in the event that they need to make-up oxygen in the main chamber. It is important that the oxygen sampler valve be relocated to avoid the problem of a spuriously high oxygen analyser reading when adding oxygen to the main chamber. It could be relocated to an area close to the carbon dioxide scrubber outlet. This would enable the added oxygen to be distributed around the chamber more efficiently and allow a more accurate analysis of the actual chamber PO_2.

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Since this paper was submitted the National Safety Council of Australia (Victorian Division) has gone into liquidation.

WOMEN AND DIVING

Margie Cole

Introduction

Scuba diving today is a rapidly growing sport. The increase in leisure time and leisure money has seen many people take up diving as an addition to their other sporting activities. The growth in the industry in general has created a large financial interest in developing ever newer and more attractive (and more expensive) and safer diving gear. The emphasis in diving has similarly changed from spearing fish and spearfishing competitions to photography, travel and marine biology. Because of these changes women have been more inclined to join their men friends, and venture into the deep.

Although these days women like to consider themselves men's equals, there are some important differences to take into consideration when it comes to safety in diving. These medical aspects have only recently been addressed and as yet there are many unanswered questions.

Historically women have been diving for centuries. The Ama divers of Japan and Korea have been commercially involved in diving for some 2,000 years. They free dive all year round to depths of 10 to 70 feet They are mainly involved in collecting shellfish and seaweed for food and medicinal purposes. Traditionally they have been women although there have been some male divers. The reasons for the female predominance are unclear but one theory is that it was because there was a belief that diving reduced male fertility and hence the women were given the job by default1. These women are fewer in number nowadays and their profession not as highly esteemed as previously. They are obviously extremely proficient divers diving all year round in waters often as cold as 10 degrees. They free dive from small boats, often with an attendant on the surface to help pull up the diver and the catch. Traditionally they wore only cotton cloths wrapped around them or even dived naked. These days many wear wet suits. They make an interesting study when considering the effects of temperature acclimatisation and cold adaptation, as well as the long term effects of repetitive diving in these conditions.

Our society seems to have taken slightly longer to accept females in a divers' role. It only takes a quick look through old diving magazines to realise the changes that have taken place. Luckily times have changed.

With all this put in perspective I would now like to briefly discuss some of the more relevant medical aspects of women in diving.

Menstruation

The effects of menstruation on different women can vary greatly. Symptoms of menstruation can include abdominal cramps, headaches, lethargy, nausea, and backache, and there are many premenstrual symptoms including fluid retention and bloating, irritability, emotional disturbances, and decreased exercise tolerance. Long-term problems of anaemia can be caused by frequent heavy menstrual blood loss. Many women however have few if any of these symptoms and are capable of normal and above normal physical feats as evidenced by Olympic athletes competing at various stages in their menstrual cycle[2].

Just as one should not dive when unwell in any way, women should not dive when experiencing severe menstrual or pre-menstrual symptoms[2,3]. Having taken this into consideration there is still some special concerns about non-symptomatic fluid retention occurring pre-menstrually. The extra fluid may impair blood flow and reduce inert gas elimination from fatty tissue. Thereby increasing susceptibility to decompression sickness (DCS)[3]. There are no studies which show these effects either way, but perhaps a conservative approach to the dive tables around period time would be wise.

Today many of the nuisance symptoms of pre-menstrual tension (PMT) and menstruation can be effectively controlled with appropriate medical management. Certainly general measures including maintenance of general fitness and good health, weight control and a balanced diet go a long way minimising these problems.

It seems from my reading that there is a big concern among women about shark attacks if they dive during their periods[3]. It is reassuring to find that there is absolutely no evidence to suggest that there is any increased danger whatsoever and therefore should not deter any keen female diver who is otherwise well.

The Oral Contraceptive Pill

"The Pill" is by far the most popular form of contraception in Australia. Australia in fact has the highest proportionate use of the oral contraceptive pill over all other forms of contraception world-wide. Australians seem to be a nation of pill poppers! So far there is no data on the effects of the contraceptive pill and diving, in particular the effects on susceptibility to DCS. There certainly are some fairly valid theoretical concerns, however.

It is known that women who take the pill have an increased clotting tendency in their blood, particularly if they are also smokers. It is now well documented that many dives within the no-decompression limits of the dive tables can produce 'silent bubbles'. These are bubbles which form in the circulation which cause no demonstrable symptoms but which can be detected using an ultra-sound echo device called a Doppler monitor. These bubbles are found in the venous circulation and are thought not to produce any symptoms because they are quickly filtered out in the lungs or the liver. The surfaces of bubbles are known to stimulate clotting mechanisms in the blood. A significant feature of decompression sickness is the effects of blockages in the vessels caused by a combination of bubbles and clots. Hence an initially small and decreasing obstruction can be transformed into a more significant one[1].

If the effects of the pill increase this clotting tendency then one can assume that the end result of silent or symtomatic bubbles would be that much more serious. This effect would b e even more pronounced in the female pill taking diver who smokes and who dives closer to the 'safe' no-decompression limits[4].

Other theoretical risk factors from the pill include other side effects, namely fluid retention, nausea, headaches and cramping. All of these are amenable to treatment[5].

Diving and Pregnancy

Having stopped our contraceptive pill because of the worry of DCS, we then may face the problems of diving in pregnancy. These risks must be viewed from two aspects. Firstly the risk to the pregnant mother, risks of DCS, trauma, fatigue, hypothermia because of poor wet-suit fit and drowning. Secondly the risks to the developing fetus from DCS, the toxic effects of increased partial pressures of gases, hypothermia, hyperthermia, and hypoxia from near drowning.

Statistical data for humans is very much lacking. Studies done have been in the form of retrospective questionnaires where females who dived during pregnancy wrote in detailing obstetric complications and fetal abnormalities.

Susan Bangassar in 1977[4] looked at a group of women of which 72 dived during pregnancy out of a total of 680 respondents. These dives included 5 decompression dives. All the babies born were normal, but there was a small incidence of complications of pregnancy; 1 premature birth; 1 septic abortion; 2 miscarriages and 2 caesarian sections. Overall not a significant increase over the general pregnant population.

In 1980 Margie Bolton[5] looked at 208 female respondents and a subgroup of 178, 109 of whom had dived during pregnancy, compared to 69 who did not. The average depth of the dives was 42 feet 20 women dived to 99 feet during the first trimester. There was a significantly higher incidence of spontaneous abortion, low birth weight, birth defects and respiratory difficulty. However the overall percentages again were still within the normal limits for the population at large.

One must accept the problems and limitations of questionnaire type surveys in that one is relying on individuals responding with accurate information.

The other source of data is from experimental studies on animals. As it is unlikely that there will ever be similar studies on humans, we must accept the limitations of species differences in both susceptibility to DCS and in differences in fetal and placental function.

In 1968 McIver[6] experienced with pregnant dogs, subjecting them to 165 foot chamber dives for 30 minutes. This produced marked intravascular bubbling in all the mothers but only 2 of the 94 fetuses showed bubbling. Interestingly the amniotic fluid surrounding the fetuses contained numerous large bubbles.

In 1974 Chen (quoted by Fife[7]) repeated the study using pregnant rats exposing them to 247 foot dives for 30 minutes. No fetuses had any bubbles despite the mothers dying of massive bubbling.

In 1978 Fife et al.[8] experimented with 7 pregnant sheep. Using an implanted ultrasonic flow meter around the umbilical artery of the fetus and another around the maternal jugular vein he exposed them to 140 foot dives. All the fetuses had DCS but no bubbles were detected in the mothers, the opposite of previous observations.

In 1980 Stocke et al.[9] repeated these last experiments and found that in fact the bubbles in the fetus were probably artifactual, caused by the surgical implants. They chamber dived both surgically monitored and non-monitored fetuses and found that fetuses which had not been operated upon did not have detectable DCS.

More recent studies on pregnant hampsters (Gilman et al.[10,11]) subjected to decompression and non-decompression dives in early pregnancy, revealed low birth weights in those subjected to decompression dives. Marked teratogenic effects were seen in the fetuses born to mothers who suffered DCS and survived to term. Fetuses born to mothers who suffered DCS and who were treated showed no statistical difference in fetal outcome from controls.

Thus it may seem from these experimental studies that the fetus is less likely than the mother to develop bubbles. However we must consider the effects of even very small bubbles on the fetus. Firstly size is important. The dimensions of important fetal vessels, for example the main arteries to the brain, kidneys, etc. could be obstructed by a bubble so small that in the mother would cause no detectable problem. The fetal circulation largely bypasses the lungs which would venous bubbles to bypass the lung filter and become an arterial embolus[12]. Again causing a much more serious problem than a similar bubble presenting in the mother.

The developing fetus is dependent on a regular supply of oxygen for normal growth and development. It may therefore suffer if the mother suffers hypoxic episodes from near drowning or aspiration.

As well as the risk of DCS, the toxic effects of raised partial pressures of gases on the fetus must be considered. We know that premature babies breathing 100% O_2 can suffer from retinal damage and blindness. Hence it is likely that the unborn fetus may suffer the same consequences of raised O_2 tensions caused by deep dives. High oxygen tensions are also thought to predispose to birth defects and fetal death in early gestation, and cause problems in late gestation of closure of the ductus arteriosus and possible prematurity[13].

These high partial pressures of oxygen are a consideration in normal deep air diving as well as in the recompression chamber if the mother needs therapeutic recompression.

The pregnant woman herself may be more at risk of developing DCS by virtue of the changes that occur with pregnancy. Increased fluid retention and increased body fat stores will allow for more nitrogen retention. Other problems such as nausea, vomiting, backache, headache, fatigue clumsiness and physical discomfort due to size, make diving more uncomfortable as well as more dangerous, increasing the risk of drowning or near drowning and subsequent hypoxia to herself and her baby.

So what then is the recommended safe diving limits for the pregnant diver? There are many different opinions on this, varying from limiting the dive to 9 m, to 18 m, to 27 m. Diving only in warm, calm, protected waters and avoidance of decompression dives have all been advised. I feel that until more is known for sure, the best solution is no diving at all. It is really a small price to pay for a healthy mother and baby at the end of the 9 months.

Susceptibility to Decompression Sickness

There is very little comparative data comparing the rate of DCS between the sexes. Men predominate on a numerical count but this is biased as there are more men actively diving. Most of the studies done have been from Air Force statistics looking at exposure to reduced barometric pressure in their trainees and some small studies from naval divers of which there is a very small percentage of females. Other statistics come from questionnaire type studies of active sport divers.

Before looking at the statistical data, we should examine the physiological and anatomical differences between the sexes which would theoretically place women at an increased risk of developing DCS. These factors are firstly an increased proportion of and different distribution of body fat, fluid shifts and fluid retention related to hormonal changes with menstruation and the contraceptive pill. Other perhaps more hypothetical differences may be an increased female tendency to vasospastic phenomena such as migraine and Raynaud's phenomenon. There may be an increased clotting tendency irrespective of the contraceptive pill as well as differences in blood flow through adipose tissue which may impede inert gas transfer. All of these create a theoretical increase in the likelihood of developing DCS. So far no statistical analysis has been made of divers requiring recompression for DCS which would help to answer these questions[3,4].

Data that is available does suggest that women are more susceptible. During the 12 year period from 1966 to 1977 a study from the US Air Force's altitude chamber indoctrination program recorded 104 individuals treated by recompression for altitude DCS. Although DCS from diving is not exactly the same the problems are similar enough to warrant looking at the data. It was found that the incidence of DCS for men was 0.09% and for women was 0.36%, that is a four fold increase in incidence. Comparing individual factors it was found (not surprisingly) that women were smaller in height, weight, and body build. One would expect these factors to be advantageous. Significantly there were a larger number of women who reported a history of vascular or migraine headaches and previous altitude reaction. Women in this study had actually attained a lower maximum exposure altitude. This also supports a finding of greater susceptibility to DCS. Case data showed that significantly more women had the onset of bends pains at altitude, i.e. earlier than men, and had more skin manifestations. Other differences noted, though not statistically significant, were that during treatment women had more relapses and required retreatment more often[3,4].

In contrast a recent study of naval divers demonstrated no increased risk compared to their male counterparts. This study from the Naval Diving and Salvage Training Centre in Florida reported in 1987 statistics comparing 28 female student divers with 487 male counterparts on 878 air and helium-oxygen dives between 120 and 300 feet with bottom times of less than 20 minutes. None of the women developed DCS while 8 men did[14].

There have, however, been naval women who have sustained diving related DCS on long-duration, experimental or saturation dive profiles. It may be that long-duration, saturation or multiple repetitive dives pose an increased risk for women whereas shorter, more typical sport dives increased risk for women whereas shorter, more typical sport dives are no more dangerous than for men[14]. Possibly this is due to the extra adipose tissue which women have, on average about 10% more, creating a capability of absorbing more inert gas. Fat tissue being capable of holding 5 times the amount of nitrogen compared to blood.

The only study in sports diving women to data was one published in 1979 by Sussan Bangassar[4]. She performed a retrospective questionnaire type survey of 649 female divers and looked at a sub-group of women instructors comparing them to a group of male instructors, all having performed a similar number of dives. She found a 0.023% incidence of DCS in the female group compared to 0.007% incidence for the males. That is it showed a 3.3 times greater incidence of DCS in women diver instructors than in men. These results however need to be looked at objectively as they are based on reported incidents rather than medically documented sickness, as well as the fact that any diver who was very seriously injured and left the sport or who actually died, did not answer the questionnaire. There is certainly room for someone to repeat this type of survey with better controls and perspective.

Physical Differences

The obvious differences in size, stature and strength in practical terms often cause no difficulties for the female diver. A fit female may in fact be better equipped to handle strenuous swimming and carrying of heavy dive gear than an unfit male. Pure physical strength and size however could play an important role when attempting to perform a rescue which involves hauling a drowning body from the water, either over the rocks or over the side of the boat.

Small size has advantages of small lung volumes and hence lesser air consumption, allowing a smaller tank size for the same dive. Women also tend to be more flexible and agile and often have an increased natural buoyancy.

There are differences in thermal balance. Firstly women have on average about 10% more body fat, most of this distributed just under the skin. This acts to retain body heat by creating more insulation. A second important factor in heat regulation is the ratio of surface area to body mass. Women who are lean, i.e. having less than 27% body fat, tend to lose heat more quickly than men of comparable fatness. This is due to the larger surface area to mass ratio. Body fatness levels above 30% body fat give men and women an equal heat loss[1,14,15].

Acclimatisation seems to be a third important factor. It seems that exposure to cold environments frequently may cause changes to the body's metabolism. The female Ama divers of Japan have been studied with regard to this and it has been found that their metabolic rates increase by up to 30% to compensate for the extra heat loss during long days of diving during the winter. In our community, men may therefore have an advantage since they tend to participate in water sports all year round and may well develop this adaptation.

For the average sports diver today, however, a well fitting wet-suit or dry suit can compensate for many physical differences and the problem of thermal regulation variations is not so great.

At the other end of the scale it should be noted that there are sex differences with regard to hyperthermia. Women are more susceptible to overheating due to a few factors. Firstly on average women begin to sweat at 2 to 3 degrees higher temperature than men. Also they have a smaller number of functional sweat glands in total. Thus females may tend to overheat when exercising or gearing up in the sun on a hot day and should perhaps take measures to cool off when sitting geared up in a wet suit[1].

Conclusions

In summary it would seem that although women can and do participate in the sport of scuba diving to the same extent as men, there are a few areas in which women need to exercise thought, commonsense and caution in order to maintain an acceptable degree of diving safety.

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This is an edited transcript of a lecture delivered in 1988 to an audience of divers.

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THE DRUG-AFFECTED DIVER

Ian Unsworth.

The drug-affected diver is not something which has been considered very much. I am going to discuss two aspects. Initially illicit drugs, Table 1, because drugs of that sort are a fact of today, and secondly I will mention drugs we tend to call “medications”, just to remind us that many medications prescribed by practitioners and self-prescribed by divers indeed do affect the diver’s ability to work or perform or just to be safe underwater.

Illicit drugs

Illicit drugs are a fact of today and it is going to be very difficult to act in this area as far as divers are concerned. I believe there are three reasons, why divers, both sport and commercial, might take drugs illicit soft drugs and hard drugs in combination with diving or going under pressure.

TABLE ONE

ILLICIT DRUGS

Cannabis (Marihuana)
Cocaine
Heroin
Amphetamines
Barbiturates
Angel Dust

One is a deliberate attempt to enhance psychiatric (yes, it is psychiatric) pleasure of drugs. This would apply to sport divers. Then, commercial divers misguidedly use illegal or illicit drugs as an attempt to enhance their underwater performance, and thirdly perhaps there is a certain ignorance among divers, both commercial and sport, that there is an additive affect of diving on a wide range of medications.

I think we should consider primarily the recreational use of these drugs. The true addict does not occur in either sport or commercial diving. By the true addict I mean someone who is so ‘hooked’ on agents like heroin that he is not going to spend his money getting a fill for an air tank, he is not going to spend his money on buying diving equipment or taking a charter boat out, he wants all his available cash to supply his habit. I think there are very, very, very, few genuine hard addicts in diving. I do not think it is possible for them to exist.

But the recreational use of drugs is, I think, very important and is very dangerous. Heroin is not commonly considered a recreational drug. They are first of all the cannabis derivatives. Probably marihuana is the easiest form to obtain it, and the commonest form of its use is smoking. The active ingredient of marihuana is THC which has the lovely name of delta 9 tetrahydrocannabinol. Cocaine is certainly now coming into fashion and it is not, as was commonly believed a year or two ago, the Yuppie drug. It is very, very much the drug of the ordinary person in the street. So we are considering the recreational use of marihuana and cocaine. Using the latest figures from the Federal Government computer on drug abuse in Canberra, in the 14-24 year old age group, 27% of both sexes use marihuana recreationally, whereas it is used by 34% of the males in that age group. In the age group of 25-39 years old, 15% use marihuana recreationally, while 20% of the males use marihuana recreationally. With cocaine in the 14-24 year old age group 0.2% of both sexes use cocaine recreationally but 0.4% of the males use cocaine. In the 25-39 year old age group 1% of both sexes use cocaine recreationally and 2% of males use the drug recreationally. These figures are not specific to divers, but these illustrate that the groups of young people among whom the divers will fall are recreational users and one would anticipate therefore that a smaller, perhaps a much smaller, percentage of usage occurs among divers.

Amphetamines are available on the illicit market and it is well known that they do enhance performance. Long distance truck drivers have been using amphetamines for quite a while and I think perhaps some divers may also be taking amphetamines.

Barbiturates are not all that common. My first close encounter with a diver taking drugs was with deliberate overuse of barbiturates in association with deep diving and therefore nitrogen narcosis. We will not consider heroin because I do not believe much heroin is used in diving if any.

I do not think that Angel dust, or phencyclidine, similar to LSD, is used at all in diving. The bizarre performance would have led us to have had a lot more diving deaths than in fact than there have been.

TABLE TWO

EFFECT OF ILLICIT DRUGS

PHYSICAL

Increased heat loss through vasodilation
Increased rate of decompression sickness, because of actions on CVS.

MENTAL

Sedation, increases narcosis
Reduction of work efficiency
Reduced perception of danger leading to ignoring safety rules, etc.

What are the numbers of these maniacs, because this is the only way to describe them, psychiatric maniacs, what evidence have we got that they exist at all? I have had to treat for spinal decompression sickness a fellow who had deliberately dived with three mates under the influence of barbiturates. So there is anecdotal evidence that people have dived, and some are probably continuing to dive, under the influence of illicit drugs. There are also reports of deaths that are available. I know of one that occurred in New Zealand. A diving instructor who deliberately smoked an excessive amount, even to his mates, of marihuana, prior to a dive from which he did not return alive. I suppose it could have been coincidental that he had a fatal diving accident after smoking marihuana, but putting the two together, certainly it would seem to be appropriate. There are other reports of incidents underwater from the use of illicit agents.

I have been doing medical examinations for diving for more years than I care to remember, nearly 20, and I suppose in that time I have come across 15-20 proposed candidates who were heavily into drugs. In fact on a number of occasions during the examination these divers, or prospective divers, were unable to prevent themselves running to the wash basin and vomiting because of a withdrawal effect. But what about the number of people who when asked, “Do you smoke” say “No, not tobacco” and one says, “Do you smoke marihuana?” “Oh, occasionally!”. I think perhaps all of us who do diving medicals have come across a few cases in our time. Now if we can winkle these people out, what about the divers who go to general practitioners who do not understand about diving. They certainly would not appreciate the effects of diving under the influence of drugs. I think there is evidence from anecdotal sources, the results of medical examinations and from death reports to suggest that diving and the use of drugs are being combined.

The effects of illicit drugs are detailed in Table 2. That is why we have to say to these people, “No you can not dive”. We have got to point out to them some of the effects of illicit drugs that are being used in a recreational manner. We have got to tell our diving friends and our diving instructors that they must teach that the recreational use of soft drugs is very much a no-no. The physical effects will be increased heat loss, the effect on the cardiovascular system which will be to increase pulse and blood pressure, and the resulting increased gas uptake will increase the likelihood of decompression sickness. The second aspect, is the mental effect of illicit drugs. A number of drugs will sedate, which increases the likelihood of nitrogen narcosis which increases the likelihood of underwater accidents and reduces work efficiency. For the sport diver this is not quite so important but to the working diver it is very important. The third aspect which could well lead to accidents going on to a fatality, is the reduced perception of danger. If divers ignore safety rules because of a reduced perception of danger, then they are swimming into trouble. We all know in diving that there are potential hazards. I believe that diving is dangerous and therefore perhaps we should get permission for an autopsy from all prospective divers.

There is the impression among a lot of people is that with cannabis, one or two "smokers" will not do any harm. They might have that in the morning or between dives at midday and then dive again in the afternoon. However with the tetrahydrocannabinol in cannabis there is a big effect on the mood, on memory and on motor coordination and it is quite sedating. This sedating effect is quite contrary to cocaine and the amphetamines. The smoker mellows, memory becomes a little impaired, motor coordination is impaired and balance, interestingly enough, also suffers, even in very low dosage. What do I mean by low dosage? One or two "smokers" of marihuana. That will give impaired perception, attention and information processing which has been very significant in such activities as flying and to which I have now added diving. THC affects the cardiovascular system. There is an increased pulse rate which will mean more uptake of nitrogen. When the diving pot smoker is upright, the blood pressure is lowish or tends to fall, very similar to postural hypotension. There is also an inhibition of sweating, which with activity underwater, may well give an unacceptable rise in body temperature. This has been shown to occur with marihuana at ordinary atmospheric pressures. This again is very undesirable underwater.

The importance of just one cigarette of marihuana is that it lasts much, much longer than the person who has used that marihuana will themselves appreciate. It will last up to eight hours after one smoke of a joint. Obviously these are very undesirable aspects of a "socially acceptable" agent. Very undesirable effects on a sport diver and obviously worse for a commercial diver. So divers must not underestimate the danger of this marihuana smoking associated with diving.

What about the once yuppie drug, cocaine, which one can snort, smoke or inject ? I include the designer drug, crack, which is fearfully potent, and add to the list the amphetamines for a little stimulation. Again there are two effects, one on the central nervous system of stimulation. The person using cocaine or amphetamine feels very, very happy or indeed can go past that state and feel extraordinary dysphoric. He might get very restless, not absolutely sure what the restlessness is due to. He may develop tremors and loss of coordination. These drugs give a reduced sense of muscle fatigue. It is only a reduction in the sense of muscle fatigue. It is not actually an improvement in the state of fatigue. It is just that the sense of fatigue is reduced, so they do not feel so tired, and they feel they can go on and on and do much more work and that they can drive much longer distances and so on. Obviously these aspects are very, very important and very dangerous to someone who is using cocaine or amphetamines and diving. With the cardiovascular system, the pulse rate is increased and the blood pressure goes up with increased gas uptake and interestingly enough, vasoconstriction occurs with cocaine. It is one of the most potent of all vasoconstrictors. Vasoconstriction can again give a rise in core temperature as heat is cannot escape easily from the body. These are extremely dangerous conditions to have in a diver and therefore we must discourage, in every possible way, prospective divers who are found to be using recreational drugs. We must get the word through to the diving community that it is foolhardy even unto death, to use these drugs recreationally and dive.

Self prescribed medications

Now to turn very briefly to some self-prescribed medications. These are perfectly legitimate, licit medications and include aspirin, antihistamines, alcohol and nicotine. Aspirin is fine when taken for pain relief. When taken after a bend there is certainly some discussion about its use. However I do not want to get embroiled in that. I will move on to the antihistamines for seasickness. This is one of the few medications that diving doctors may prescribe or get their patients to take because a diver who travels by boat, having taken a non-sedating antihistamine and who does not suffer seasickness is probably a safer diver than one who gets there feeling absolutely terrible, having vomited all the way out to the dive site, but having got there feels he must dive because he has paid his money. So I think the legitimate use of anti-seasickness medications is appropriate.

What about alcohol and nicotine ? These are often not considered in relation to diving, but they are the commonest "drugs" that we see used ,and their effects are shown in Table 3. I must emphasize excess alcohol. Excess alcohol is often taken by foolhardy divers the night before. There is an old adage I was taught many, many years ago when I was a young lad taking up diving, that tomorrow's dive begins today. People who go to parties before tomorrow's dive are really acting very irresponsibly. What effect does excess alcohol have on the next day's dive? Dehydration occurs as a result of the output of antidiuretic hormone (ADH) being reduced and as a result of the antidiuretic hormone being turned off, increased urine is produced. Dehydration has the effect of increasing plasma viscosity and plasma viscosity has a very large effect on the stability of venous gas emboli (VGE) and we know venous gas emboli occur following many perfectly normal dives. They do not usually go on to produce decompression sickness. But if there is increased plasma viscosity, it stabilises these little gas bubbles and therefore it is quite likely that they will initiate early decompression sickness. So by having excess alcohol the night before and becoming dehydrated, one can initiate early decompression sickness from VGE.

What about smoking? Nicotine, among other things, increases the heart rate and raises the blood pressure. Not very good for a diver as they will increase nitrogen uptake. It stimulates tremors and reduces work efficiency, and produces small vessel constriction. Nicotine from smoking may well contribute to a higher incidence of decompression sickness because gas is trapped within muscle masses by the nicotine vasoconstriction. Another problem of smoking and diving is micro-lung rupture, which I have been mentioning for a long time now but which has not really had very much recognition. Let me explain what I mean by micro-lung rupture. Heavy smokers produce a lot of mucus and this mucus can be deep down in the lung, in the respiratory bronchioles or even just outside the alveoli. If gas within these alveoli is entrapped by this thick tenacious mucus during ascent one can get small areas of lung, very small areas, almost individual alveoli, rupturing due to the expansion of gas which is not able to escape because of mucus. It is not the massive lung rupture that we commonly associate with pulmonary barotrauma, but small discrete areas of lung being damaged. People often say of middle aged heavy smokers "So and so is just not quite himself after this dive. He seems just to have something not quite right with himself". No one can put their finger on exactly what it is. I believe this syndrome is the result of micro-lung rupture. It is not the massive pulmonary barotrauma that we are all taught about. This is discrete micro-lung rupture that will not produce any signs such as coughing up of blood, but will release into the circulation very small amounts of gas which will be entrained and disappear up one of the carotid arteries to the brain. I think these small amounts of gas produce changes such as alteration in personality albeit transiently. Now the final problem with smoking is carbon monoxide production. This decreases oxygen carriage, which is not particularly good in an activity where you might have to work hard underwater with increased requirements for oxygen.

TABLE THREE

COMMONEST "DRUGS" IN DIVING

ALCOHOL
Decreased secretion of antidiuretic hormone (ADH) leading to increased urinary secretion and dehydration.
Dehydration increases plasma viscocity which stabilises venous gas emboli (VGE).
These stable VGEs initiate earlier onset of decompression sickness.

NICOTINE
Increases heart rate, raises blood pressure. Increases cardiac output, increases gas uptake.
Stimulates CNS tremors and decreases work efficiency
Produces small vessel constriction, reduces removal of gas from the tissues.
Traps gas.in small airways.

Prescribed medications

Then there are prescribed medications. There are the anti-inflammatories, aspirin and non-steroidal anti-inflammatories, anxiolytics and the benzodiazepines. The benzodiazepines include such agents as nitrazepam, diazepam, etc. These can be prescribed for concerned and anxious divers or for people who might then go on to sport diving. There are cardiac drugs, antihypertensives, ß-blockers, diuretics and digoxin. There are anti-epileptics. There are bronchodilators for asthma. There is insulin or oral hypoglycaemic agents for diabetes and drugs for thyroid dysfunction.

There are some specific effects that may cause trouble. The antidepressants will give some degree of cerebral depression and will worsen the problems of nitrogen under pressure. Antihistamines affect people differently and there are some which do not produce drowsiness, but any antihistamine will synergise with nitrogen to produce worse nitrogen narcosis. Among the antihistamines used for seasickness there are some which will produce drowsiness. It is well worthwhile a diver shopping around before he goes on a boat and trying, over a period of two or three weeks, different anti-seasickness preparations to find a compound that does not make him or her drowsy.

Patients with cardiac problems who have been prescribed ß-blockers should not dive because the ß-blockers will reduce the person's tolerance to exercise. If a situation arises during a dive when maximum effort has to be used to get out of a problem then a ß-blocker may well jeopardise that diver's safety. Certainly those taking ß-blockers and digoxin should not dive because of reduced tolerance to exercise. Postural hypotension can occur with antihypertensives which may produce a change in the level of consciousness and can, under the stress of diving, produce arrhythmias. People on antihypertensives who want to take up diving really should be discouraged unless they are only on very, very small amounts of medication.

Other medications which can cause problems for divers are the bronchodilators for asthma. I believe that active asthmatics are at very, very profound risk in diving and no one in their right mind, certainly no diving doctor, should allow active asthmatics to dive. One has to explain the reasons why one is refusing an asthmatic. One cannot say to a person, "I am sorry, no diving, you are an asthmatic. Good bye!" They want to know why. Now it is only reasonable that they be given an explanation. An explanation which seems to me to be most appropriate for these people includes discussing Boyle's Law, ruptured lungs, sudden unconsciousness and drowning, instant death and so on. They want to know why they can not take their Ventolin and dive. There is some evidence that salbutamol is not particularly active under pressure. The problem is that if they were to use their bronchodilator at the beginning of a dive the effect is waning at the end of a dive which is precisely the time when it is most required to prevent problems.

It is generally accepted around the world that people on insulin should not dive. However some of the clinicians who care for diabetics are becoming agitated that we do not let their very fit young people on insulin dive. I think there were moves afoot to have a big conference, here in Australia, between diving doctors and physicians who manage diabetics on this very point. Why do we not like diabetics diving? Because of increased platelet adhesiveness, an increase in thromboxane and a reduction in prostacyclin which can cause decompression sickness to occur earlier. When decompression sickness does occur in diabetics it tends to be worse than in non-diabetics. The problem of decompression sickness in people who are using insulin is a very real one. Also there can be problems with exercise, from blood sugar level changes and changes in consciousness.

We do not allow people taking antiepileptics to dive because epilepsy can break through what is successful drug management on the surface when underwater, because of the increased partial pressure of oxygen from breathing compressed air at depth and the risk of an increase in arterial carbon dioxide, which often occurs when using scuba gear.

We as diving doctors should be on our guard when asked to see prospective divers who are on any of this range of quite legitimate genuine medication. In very many instances it is probable that they are really not suitable for diving and we should therefore recommend that they do not dive. One can say to them that if they ever consider diving and they went off diving against advice they would be a great liability not only to themselves, but to their diving companions. It is for this reason that we must strongly advise these people not to dive, or they may very soon find that the sun would set quite quickly on their existence.

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REASONABLE ASSUMPTIONS AND GOOD INTENTIONS MAY PROVE FATAL

Douglas Walker

The essentials of this tragedy appear simple, visitors from interstate make a deep dive together and one drowns. The investigation shows that the victim was overweighted and both were very inexperienced though trained and having an advanced diver certification. They had entered a low-air state after a failed search for the anchor and decided to make an open water ascent. The buddy was started to ascend a little ahead of the victim, a routine they had apparently developed on their (few) previous dives (i.e.. during training). Separation occurred when or before the buddy became critically low on air, inflated his buoyancy vest, then ascended rapidly the remaining distance to the surface. The victim was later found on the sea bed, weight belt on, remaining tank air insufficient to inflate his vest.

Closer examination of the genesis of the case shows a complex interplay of misunderstandings and minor lapses which bypassed the normal safety checks designed to prevent what in fact occurred, two inexperienced divers buddied together for a dive far deeper than one at least had ever previously made.

The string of circumstances began when the two divers found they were to visit another city on business at the same time and decided to arrange to have a dive while there. Their training had been recently completed, apparently from the same dive shop, and they were friends. As both were intelligent men they had impressed their instructor and had managed to take an initial Open Water course which they immediately followed by an Advanced Diver course. Although the rules were probably “bent” somewhat the result was that three weeks from their first instruction in scuba they held certificates which informed both them and others that they were Advanced divers. It is unfortunate that they clearly believed this. They had a total of nine dives logged at this time, all made as pupils, to depths of either 20 or 40 feet except for a single short dive to 80 feet depth. It is probable that the buddy later made an additional dive because they talked later about a wreck dive, talk which lulled others into accepting their apparent status as people who had made 120 feet dives. The dive to be related took place six weeks from their introduction to diving.

In response to their request for a diving contact their instructor phoned one of the dive store’s suppliers who lived in the city they were to visit. He correctly stated that they had been good pupils and held Advanced Diver certification, no mention being made of their actual diving experience. Later a phone contact was made with the instructor’s acquaintance by one of the divers in order to arrange where they were to meet him and where to hire some scuba equipment. There was some discussion of possible diving locations, without mention of their inexperience surfacing from the conversation. Although this contact, an experienced diver made payment for the boat hire, when the two divers attended at the dive shop they were charged not only for the diving equipment which they were hiring but also for the proposed dive, and the charge was that for a deep dive. Although a check was made to confirm that they held certification of training there was no questioning of their having sufficient experience to make the proposed deep dive. Later the dive shop owner stated that the charge was made in error but this does not alter the facts as here recorded.

The two visitors were surprised when they found there were three other divers coming for the dive, diver friends who their contact knew would also appreciate the opportunity this boat hire presented of making a wreck dive. The chatter while waiting for the arrival of the boat, and while its driver gave details of the wreck, appeared to confirm that they made wreck dives and were experienced divers. Nobody thought to question them on their experience, their evident self confidence was so well matched to their management of their diving equipment that no suspicions arose. The boat driver, a licensed coxswain, was not a dive master nor employed as such, although he was a diver and had first aid training, so he had brought no diving equipment for himself though there was a spare air cylinder to place on the line at the decompression stop and an oxygen cylinder for use if a diving emergency situation arose.

The wreck lay somewhat scattered over the sea bottom, at a depth of about 43 m (140 fsw) and the anchor was set in this area. As one of the other divers expected to have ear trouble with equalisation it was decided that he and his buddy should dive second so that should his fears come true his buddy need not miss the dive but could join the last pair, the victim and his buddy. As it turned out, he had no difficulty and the last pair descended as intended together. They each found they had some difficulty with equalisation but reached the sea bed, one of the other divers witnessing their arrival at the anchor. He later reported that one of them seemed to be overweighted and swimming rather more vertically than horizontally as evidence of this but the victim's buddy reported they had no problems. It is not known whether either used his buoyancy vest as an aid to correcting any such problem.

When their planned no-decompression dive time expired they expected to ascend the anchor line but could not find it despite the reportedly good visibility, Soon both saw that their contents gauges indicated they were becoming low on air so they agreed with each other to make an open-water ascent. As on previous occasions, during their training, the buddy started to ascend a little ahead of his friend but believed he was close below him because bubbles were rising past him. After he had ascended to about 18 m (60 feet) depth the buddy realised that he was nearly out of air so he inflated his buoyancy vest, which had the effect of taking him rapidly to the surface. There he was able to signal to the dive boat that he was safe, then managed to swim to it. He was helped aboard and immediately laid head down and given oxygen as he seemed distressed and had come up rapidly and without decompression stops. The victim failed to surface and it was realised that he must be dead.

The coxswain was in the difficult situation of having responsibility for an ill diver and another diver was missing and certainly drowned. He correctly sent a radio notification of the incident and concentrated on giving treatment. Because he was not employed to shepherd the dive party the aid he was able to provide was fortuitous. Another dive boat was sent to offer assistance and he then borrowed scuba equipment from it and dived with one of the experienced divers it was carrying. By now an hour had passed. They found the victim lying on the sea bed in the wreck area. His buoyancy vest contained only a little air so they tried to inflate but obtained no response when they used the power inflator, apparently because the tank pressure was too low for the task. They then made an attempt to orally inflate the vest but failed so they ditched the weight belt and the body began to float upwards. For reasons of safety they allowed it to ascend unaccompanied and they then made a slow ascent with decompression stops. It was their impression that the victim was wearing excessive weight and they noted that they had more air remaining at the end of their longer and more strenuous dive than the victim (who had 30 bar remaining), both indicators of inexperience.

When the equipment was tested a recompression chamber was used rather than the conventional open water diving test. It was noted that the buoyancy vest inflated in 10 seconds at the surface but took 45 seconds at 43 m depth. The failure of the vest to inflate when the divers who located the body used the power inflator may have been rather the result of the low rate of filling deceiving them into a belief that nothing was happening rather than a result of the low air pressure in the scuba tank. An initial suggestion that the slow inflation was a sign of vest fault was discounted and described as being what should be expected for this depth. Once again, low air and the failure to ditch the weight belt were a fatal combination for a diver separated from his buddy.

It is of interest to note why the equipment was tested in a recompression chamber rather than the sea as was routine on previous occasions when the police diving section had tested diving equipment. The reason was that police divers are bound now by the same regulations as govern commercial divers, these limiting depth for the use of scuba to less than 43 metres, a limit on depth not applying to recreational divers though most of them have sufficient common sense to avoid deep dives unless their training and planning are tuned to the proposed dive. Had the police wished to test the buoyancy vest in the sea they would have had to use a surface supply diver with a tender, stand-by diver, and recompression chamber ready at the surface. This is reminiscent of the pre-scuba days of hard hat divers with standard gear where the expense of such topside support was a complete bar to non-commercial diving. However it needs to be remembered that recreational divers can avoid diving when the conditions are unpleasant, unfavourable or possibly unsafe, and for greater durations than would be safe using a scuba supply. Nonetheless the contrast in perceived safety requirements for dives to similar depths may seem noteworthy. The police divers having to spend a week preparing for a deep dive by making dives to increasing depths and having a dive group of five while the amateurs could legally (and usually safely) dive without any special predive preparation or topside back-up party. However it was the lack of experience rather than lack of a stand-by diver and a line which proved fatal to this diver.

The pathologist reported finding signs of degeneration in the tissues but saw "no evidence of air embolism in the blood of the right ventricle". As the autopsy was conducted without undue delay and decomposition changes are not usually thought to require comment except when severe, he may have been seeing post death release of tissue gas, the expressed expectation of finding air in the right ventricle indicating a possible lack of understanding that in diving related air embolism the site of air entry is pulmonary and not systemic, as occurs in cases following trauma or surgery. It is likely that death was from drowning when he found himself unable to ascent due to excess weights and his air supply became difficult to breathe.

Comments

This tragedy occurred as the final result of a series of sins of omission, each one individually minor and non fatal in nature. Nobody did anything terribly incorrect but neither did anyone remember Murphy's Law. Those involved were trained and intelligent and well intentioned but they failed to check that matters were as they appeared to be. The initial mistake was the issue of an Advanced Diver certification to divers of such limited experience, and a failure to convey to them their continued status as grossly inexperienced divers. It was this failure which made the tragedy possible.

Next came the communication breakdown, totally correct but incomplete information being provided with the request by their instructor to another person concerning their status as divers. Their possession of the correct documentary authority to confirm their "advanced" status led to an omission of what would have been an automatic, checking of their experience, had this been a dive shop organised boat dive. Their having an unjustified belief in their diving skills (as contrasted with their undoubted knowledge) led the others on the dive trip to forget to enquire concerning their diving abilities. All such factors were in place before the dive commenced.

Such was their confidence that the two divers brushed aside comments suggesting that they were overweighted for the proposed dive, forgetting their book-learning concerning depth related loss of wet suit buoyancy. Their confident management of their equipment and talk of wreck dives made easy the very natural decision of the other divers to take their usual dive partners rather than partner the visitors, the good visibility making this appear to be a safe and simple dive.

Failure to locate the anchor when the time for ascent drew near led them to expend precious air in their search for it, so they were close to a critical low-air state when making their decision to ascend. It was here that a fault which they had acquired during training produced their final joint error in that when they commenced their ascent the victim was below and therefore out of sight of his buddy. The final actions of the victim cannot be known but he may have found his air less readily available and his buoyancy vest apparently failing to fill when the inflation button was pushed, and forgotten there was the option of dropping his weight belt.

The final item in this catalogue of misunderstandings and procedural errors was the autopsy report, although this is more a matter of conjecture than established facts. Certainly a vigorous dive to 43 metres would result in enough air being dissolved in the tissues to require subsequent elimination of excess gas after returning to the surface. This can occur via the lungs in the living but occurs in the tissues where death has prevented the circulation from assisting this task.

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THE FLYING BENDS

A review of altitude decompression sickness with case reports, from hypobaric chamber operation at RAAF Base, Point Cook.

Marcus W. Skinner

Introduction

The Royal Australian Air Force (RAAF) Institute of Aviation Medicine has conducted hypobaric chamber training (Fig. 1) at the RAAF Base at Point Cook, Victoria, since 1962. All initial entry trainee aircrew (pilots, navigators, engineers and loadmasters) of the RAAF, Royal Australian Navy, Army and Air Traffic Control trainees undergo high altitude (hypobaric pressure) training. Experienced military pilots undergo refresher training at intervals of three years. The hypobaric chamber at Point Cook is also used for other members of the Australian Defence Force, overseas defence members and for civilians who require experience in the pressure changes of high altitude, including private pilots, glider pilots, balloonists and Nepal trekkers.

Air Force members who undergo very high altitude decompression to 13,500 m (45,000 ft) with predenitrogenisation include RAAF pilots and RAAF medical officers. Members undergo hypobaric experience training to prepare them for a rapid decompression, simulating the loss of cabin pressure in a military aircraft at high altitude. The effects of hypoxia and pressure breathing are also experienced in the chamber.

For the inexperienced a rapid loss of cabin pressure when at high altitude can be a frightening experience as has been clearly demonstrated in recent civilian aircraft accidents. The sudden exposure to rapid lowering of pressure is usually accompanied by loud noise, rapid drop in ambient temperature and sudden appearance of fog, all combined with rapid gas expansion within body cavities, giving rise to typical rapid pressure change symptoms such as ear pain and discomfort, abdominal distension, belching and flatus.

This article presents a review of hypobaric decompression sickness and illustrates this with some case reports.

FIGURE 1. Aircrew trainees undergoing hypobaric simulation at RAAF Point Cook.

History

In the year 1783 near Lyon man realised his dream of ascending to the heavens by means of a balloon, but it was not until 1934 at the Army Air Services Aero Medical Laboratory at Wright Field, Dayton, Ohio, that theoretical and practical investigations into many new aspects of Aviation Medicine occurred. It was at this time that research into the new entity, labelled by Armstrong "aeroembolism" or dysbarism (now called altitude decompression sickness), was commenced. Notably, this was over 100 years after Robert Boyle reported his experiments on the effects of pressure changes on experimental animals.

Decompression sickness (DCS) resulting from exposure to altitude is similar to that occurring after decompression from a high pressure environment, as in diving or caisson work. The effects of diving and caisson work exposure have been clearly recognised and studied for over 100 years (Triger in 1841 noted cases of decompression sickness in caisson workers) but only in the past 45 years has altitude decompression become important with flights into significantly hypobaric environments.

In the 1930s Armstrong[1] first demonstrated the vaporistion of body fluids at 19,000 m (63,000 ft) (now called Armstrong's line) and was the first to point to the dangers of decompression in flight. In the studies of Armstrong and Heim[2] on the effect of flight on the middle ear, where humans were systematically exposed to simulated altitudes in a decompression chamber, they demonstrated the fact that exposure to high altitude caused symptoms similar to those of caisson disease. Armstrong pointed out that the basic physical mechanisms were the same, whether a subject "ascended from four atmospheres to one or from one atmosphere to 0.25 atmosphere[4]".

Other countries were slow to follow the American lead in Aviation Medicine research. In 1939 the Royal Air Force Physiology Laboratories were only housed in a hut at Hendon and prior to World War II the Luftwaffe had only just commenced research into medical aspects of high altitude flight in hypobaric chambers using human subjects.

In actual flight operation in World War II[3], even with rates of ascent of 910 m (3,000 ft) min as in the P-51 Mustang and Griffon-engined Spitfire, actual symptoms of altitude decompression sickness were rare. (This was probably due to the common practice of washing out nitrogen by pre-breathing 100% oxygen on the ground prior to flight.) Most commonly DCS was observed in bomber crews working in cold depressurised areas under physical stress.

Prior to 1959, over 17,000 cases of altitude decompression sickness were reported in numerous publications. Of these, 743 were reported as serious, including 17 fatalities.

Over the next two decades the incidence of altitude DCS decreased with increasing awareness of the condition, improved treatment regimes and facilities. In 1963 Downey[5] showed that bubbles produced in vitro in human serum cleared when compression to greater than sea level pressured occurred.

In 1969 Fryer published an extensive monograph on the various aspects of altitude DCS[6]. Between 1975 and 1985 90 cases of altitude DCS were reported in the Air Force Safety Journal (USAF)[7]. The altitude decompression sickness mishap rate was quoted in the range of 0.18-0.38 incidents per 100,000 flying hours, with trainer and cargo aircraft having greatest incidence. Importantly 68% of cases occurred between 5,500 m and 7,600 m (18,000 to 25,000 ft). The last reported fatality due to altitude DCS was in 1988 and involved a 51 year old USAF pilot[8].

Advances in technology have enabled the development of systems capable of transporting man into increasingly more hostile pressure environments, both hypobaric and hyperbaric. However, the understanding of physiological consequences of this exposure was poorly understood and the development of practical life support systems and treatment of patients exposed to these hostile pressures lagged behind the scientific progress. These consequences are now much more predictable and effective, safe advice can be given to individuals who wish to partake in diving and flying environments.

What is altitude decompression sickness and when does it occur?

Altitude decompression sickness is a well recognised consequence of exposure to hypobaric conditions in aircraft and hypobaric chambers. The same physical principles apply to hyperbaric conditions although the precise mechanism has never been unequivocally determined in either. It is clear that as the ambient pressure falls bubble formation occurs in the gas saturated body tissues. Saturation is due to the relatively poor solubility of nitrogen in blood so that the rate of fall of the partial pressure of nitrogen in the tissues on ascent to altitude lags behind that of the ambient pressure, in exactly the same way as ascent from depth in diving.

The mechanism involved in both altitude and diving decompression sickness are identical[9]. Studies on the factors influencing bubble formation show that significant differential pressures are required for bubbles to form spontaneously. It is not the aim here to summarise all the theoretical evidence, suffice to say that the tendency for bubbles to form is greater as the difference between the two pressures increases. Some nucleus, such as vessel irregularity, appears to be needed around which bubbles form.

The main factors[10] that influence the incidence of altitude decompression sickness, including scuba diving, are considered below. Interestingly Balladin[11] clearly showed venous gas bubbles in humans at altitudes of 910 m (3,000 ft) three hours after a no stage decompression dive to 50 ft.

Altitude Exposure

The threshold altitude has been reported as 5,500 m (18,000 ft)[12], but may be as low as 3,000 m (10,000 ft)[13]. Evidence at the USAF School of Aviation Medicine at Brooks Air Force Base in Texas indicates that bubble formation in body fluids may occur at this lower level, although these bubbles may not always be symptomatic. A study by Malconian[14] illustrated that altitude decompression sickness occurs at relatively low altitudes with repeated exposure to 4,500 m (15,000 ft). With increasing altitude above 5,500 m (18,000 ft) the incidence increases.

Rate of Ascent

The rate at which altitude is achieved is important. Contrary to earlier expectation the concept of explosive decompression sickness ,as might be expected when ejecting from an aircraft pressurised to 2,100 m (7,000 ft) cabin altitude to an environment at 13,600 m (45,000 ft), has been difficult to demonstrate experimentally below 19,000 m (63,000 ft) (Armstrong's Line[15]). A greater physical risk is hypoxia and loss of consciousness in 12-15 seconds[10]. The risk of barotrauma is also high[16]. Exposure to environmental pressure less than the vapour pressure of water at body temperature, higher than 19,100 m (63,000 ft), results in immediate and complete anoxia and ebullism (the boiling and outgassing of body fluids)[17]. Re-exposure, repetitive non-pressurised ascents to 7,600 m (25,000 ft), have been shown[4] in USAF studies to predispose aircrew to DCS. The decision by aircrew to remain at an altitude in excess of 5,500 m (18,000 ft) for mission requirements following depressurisation led to 68% of all USAF altitude DCS incidents. Many factors that influence the incidence of diving decompression sickness also correlate with the hypobaric environment.

Sex

Studies on female astronauts called upon the participate in extra-vehicular activities and exposed to hypobaric suit pressures clearly established a higher incidence of altitude DCS in females. The female:male ratio of altitude DCS was 3:1.

Age and Body Build

Early clinical analysis of thousands of altitude chamber decompressions during World War II revealed that relative susceptibility to altitude DCS increased by 9 fold between the ages of 18 and 28 years.

Exercise

It is well established that exercise at altitude increases the incidence and severity for altitude DCS. The effect of heavy exercise is equivalent to an increase in the altitude of exposure of 1,500 m (5,000 ft).

Previous Injury

No convincing evidence exists to associate previous injury with a higher incidence of altitude decompression sickness on theoretical grounds, but altitude DCS is seen more commonly in previously injured limbs.

Alcohol

The after effects of alcohol ingestion increases the susceptibility to altitude DCS.

Preflight Denitrogenisation

Preflight inhalation of 100% oxygen decreases the incidence of bends in proportion to the time of denitrogenisation. 30 minutes of breathing 100% oxygen will provide a significant degree of protection.

Flying following scuba diving

With many diving holiday packages now offered people fly to their dream diving destination, dive intensively and then fly home. Many are naively unaware of the dangers they are taking by extending their diving to the limit of their holiday.

Flying after diving can predispose to decompression sickness unless there has been sufficient time (surface interval) to allow excess nitrogen to diffuse out of the tissues. When the ambient pressure is reduced even further by climbing to altitude, bubbles may form.

Decompression sickness has been described during flight when scuba diving had taken place before departure[20].

Studies indicate that silent venous gas bubbles form at low altitudes. This has been confirmed by the intravascular presence of bubbles at 900 m to 3,000 m (3,000 to 10,000 ft) cabin altitude with ordinary no-decompression dives preceding altitude exposure by three hours[11]. It was noted that bubbles appeared within minutes of flight. This phenomenon was also seen when flying 24 hours after diving, but at a cabin altitude of 7,600 m (25,000 ft). A causal relationship between these Doppler (ultrasound) intravenous bubbles and the development of symptoms has yet to be established.

There is a small risk of decompression sickness after diving not followed by flying, even if the decompression tables are obeyed accurately. There is also a very small risk that silent stationary bubbles, which are just too small to cause symptoms at surface pressure, will do so with decompression to low altitudes. Cases of DCS have been shown to worsen during low-level helicopter transport[21], although in the main helicopter transport is safe.

Edmonds et al[22] advise that flight in an aircraft at cabin altitudes of 1,500 to 3,000 m be only conducted at least two hours after a no-stop (no-decompression) dive and 24 hours after a dive needing decompression stops.

In 1982 the British Medical Advisory Committee adopted safety guidelines for flying after diving. They recommended that for a no-decompression dive, with total time under pressure of less than one hour, the required time before flight to cabin altitude of 600 m (2,000 ft) minimum of two hours and to 2,450 m (8,000 ft) a minimum of four hours. All other compressed air dives required 12 hours before flight. Military aircrew who dive are restricted from flying duties for 24 hours.

Aeromedical evacuation of patients with decompression sickness

Movement of a patient with decompression sickness sometimes poses problems when the hyperbaric treatment facility is located at a significant distance from site of injury. Most aircraft are pressurised to 1,500 to 2,450 m (5,000 to 8,000 ft) cabin altitude and therefore flight will increase the size of bubbles.

Dully[22] showed that complacency and lack of rapid treatment for decompression sickness can result in severe complications, and that for long distance travel, movement by air is most appropriate although not without danger. If bubbles are causing pain then as they enlarge symptoms will worsen. Cases of decompression sickness are therefore best transported by aircraft at sea level pressure. The C-130 Hercules operated by the RAAF is capable of maintaining sea level pressurisation at relatively high altitude (5,800 m) (19,000 ft) and is therefore an ideal aircraft for this purpose when transportable chambers are unavailable.

For relatively short flights and for areas which do not have pressurised fixed-wing aircraft, the helicopter offers an excellent alternative. A study by Reddick[21] shows that movement of patients with decompression sickness by low-level helicopter flight is both safe and effective, especially when a pressurised aircraft is neither available nor practical.

Altitude Decompression Sickness from Hypobaric Operations

Hypobaric chamber exposures have proved to be a very safe and cost effective way to introduce flyers to the physiological limitations of unpressurised flight and the correct use of life support equipment. Deaths are rare, however fatal case reports[8,24,25] clearly demonstrate the rapidity with which seemingly mild symptoms can progress.

In the US Army, hypobaric chamber operations over a 63 month period showed the overall incidence rate for decompression sickness was 1.38 per 1000 exposures. The rate for technicians monitoring these was 6.16 per 1000 exposures and the rate for students was 0.64 per 1000 exposures[26]. The reason for this substantial difference is complex but the technicians have repeated exposure, are generally older and go to higher altitude.

All Australian defence force members who undergo hypobaric instruction and suffer, either during or after an actual decompression, untoward symptoms have a Decompression Chamber Physiological Incident report completed. This aims to develop improved control and treatment of chamber incidents, to monitor aeromedical training procedures and to evaluate individual recovery.

Since 1984 a total of six cases of altitude decompression sickness have been recorded from hypobaric chamber runs at Point Cook giving an incidence similar to that of the US Army hypobaric chamber operations.

Basic Flight Profiles

There are three basic profiles carried out in RAAF hypobaric chambers:

A The type A profile is designed to provide a rapid decompression from 2,450 m (8,000 ft) to 7,600 m (25,000 ft) to allow students to experience hypoxia at 7,600 m (25,000 ft) and to familiarise them with the use of oxygen equipment.

B The type B profile is designed to demonstrate the problems of vision at night and in particular, the effect of hypoxia, with decompression to 4,500 m (15,000 ft) for 35 minutes to allow for dark adaption.

C The type C profile is designed to provide rapid decompression from 7,600 m (25,000 ft) to 13,600 m (45,000 ft) and allow students to experience pressure breathing at 13,600 m (45,000 ft) (for 30 seconds), then hypoxia symptoms at 7,600 m (25,000 ft) and "free fall" from 7,600 m (25,000 ft) to 3,000 m (10,000 ft) using the emergency oxygen cylinder.

Case Reports

CASE 1
Onset of joint pain at altitude and persisting after descent.

A 33 year old RAAF member was undergoing initial decompression training. He was decompressed to 7,600 m (25,000 ft) and after seven minutes at this altitude he developed pains in the right elbow which increased in severity. Simultaneously right shoulder pain was noticed. On return to sea level pressure he complained of increasing pain in his right arm. A tentative diagnosis of joint DCS was made and he was put on 100% oxygen, rested, given fluids and transferred by road to a hyperbaric chamber for therapy. After 30 minutes on 100% oxygen his pain had almost gone but when oxygen was ceased during casualty assessment, prior to hyperbaric treatment, his symptoms returned to full. He was compressed on oxygen to 18 metres of seawater for five hours and his symptoms completely resolved. The significant predisposing factors in this incident were a mild injury to his right elbow one week prior to "decompression" and that he had flown by an HS-748 aircraft, along with other members from another RAAF Base, in the morning prior to chamber run. The duration of the flight was 0.7 hours, peak cabin altitude of only 300 m (1,000 ft) and there was no recent diving.

CASE 2
Joint pains and skin symptoms two hours after chamber flight.

A 37 old RAAF pilot who assisted in the running of the hypobaric chamber underwent a 7,600 m (25,000 ft) standard A run decompression. He completed it with a minor degree of apprehension due to ear pain on descent, but sustained no otic barotrauma. Two hours after finishing the decompression run he developed abnormal skin sensations over his forehead and back along with marked temporomandibular joint pain. Symptoms were only partially relieved by 100% oxygen. The patient was transferred to a hyperbaric facility and was treated on RN table 62 with rapid and full resolution of all symptoms. The significant predisposing factor was that the member forgot to undertake prebreathing 100% oxygen before recompression.

CASE 3
Joint pain on descent from altitude.

A 23 year old Army pilot undertook a type A hypobaric chamber run. He remained at 7,600 m (25,000 ft) for 15 minutes and on descent at 4,100 m (13,500 ft) he complained of left elbow pain. There were no predisposing factors. With 100% oxygen at ground level, the pain ceased. A hyperbaric specialist was consulted but because local recompression was not available and as the patient's state was satisfactory, conservative management was undertaken, with full resolution of symptoms.

CASE 4
Joint pains left elbow.

A 23 year old RAAF pilot undertook a type A hypobaric run to 7,600 m (25,000 ft). After eleven minutes when descent to 4,100 m (13,500 ft) was commenced, the member complained of left elbow pain. The "flight" was aborted and the member placed on 100% oxygen with rapid resolution of his symptoms. There was no recurrence of pain. The member had not been diving and had no other significant predisposing factors.

CASE 5
Possible neurological decompression sickness.

A 31 year old chamber attendant participated in a standard A run to 7,600 m (25,000 ft) without incident. After the decompression run he developed slurred speech and right C8 dermatome dysaesthesia. He was confused, with blurring of his vision. He was urgently transferred to a hyperbaric unit, where with hyperbaric treatment, symptoms resolved completely. The only predisposing factor was that he had been jogging the evening prior to the decompression.

CASE 6
Neurological and joint decompression sickness.

The patient, a 41 year old Naval officer, underwent a type A flight without incident. 25 minutes after the flight he noticed right shoulder pain and this persisted until he fell asleep on the evening of the flight. It was not present the following morning. He did not make his symptoms known at this time, although the pre-flight brief clearly requested immediate notification of any symptoms. He underwent a second hypobaric run to 4,600 m (15,000 feet) and seven minutes into this he complained of marked tingling and pain in the right shoulder. The run was terminated and he was placed on 100% oxygen. Within 30 minutes he had no further symptoms but shortly after removal of his oxygen mask his symptoms returned and he developed slurred speech. It was at this stage the previous day's symptoms were admitted. He was put back on 100% oxygen and evacuated by a C-130 Hercules aircraft, pressurised to sea level, to a hyperbaric unit where with treatment his symptoms completely resolved without sequelae.

Discussion

The clinical manifestations of altitude DCS are varied. Table 1[27] presents the relative incidence of symptoms of altitude DCS.

The uniformly prompt response to 100% oxygen and hyperbaric therapy in all of the cases presented indicates that these patients were correctly diagnosed as suffering from decompression sickness.

The most common manifestation observed in the cases from hypobaric operations at RAAF Point Cook were joint and limb pain. In all these cases local pressure by means of a tight bandage or pneumatic cuff relieved the pain.

The USAF student exposures in hypobaric chambers show that joint pain symptoms alone predominated in 60% of treated cases with or without delayed onset.

TABLE 1

RELATIVE INCIDENCE OF SYMPTOMS OF ALTITUDE DECOMPRESSION SICKNESS

Symptom	**Incidence (%)**	
	8,500 m (28,000 ft) for 2 hours	**11,200 m (37,000 ft) for 2 hours**
Joint and limb pain	73.9	56.5
Respiratory disturbances	4.5	6.5
Skin disturbances	7.0	1.6
Visual disturbances	2.0	4.8
Neurological disturbances	1.0	.0
Collapse	9.0	25.8
Miscellaneous	2.5	4.8

Itching, tingling (the creeps) and formication often occur at altitude and are usually transient and only rarely progress to more serious manifestations. More severe skin manifestations of altitude DCS are possibly due to embolism[27].

Respiratory disturbances, the chokes, are an uncommon manifestation of altitude DCS but if the exposure to altitude is maintained the chokes almost invariably progress to collapse and death. The patient is pale, restless, peripherally shutdown but clammy with increasing bradycardia and hypotension. The patient then may lose consciousness. Fortunately it is rare.

Unlike divers, aviators rarely experience spinal cord manifestations of neurological decompression sickness, although cases 5 and 6 both appear to have developed neurological decompression sickness. Paralysis, paraesthesia and fits occur but no disturbance of smell or taste has been reported. Labyrinthine involvement is very rare.

The confusing and varied picture of patients with neurological decompression sickness has been readily mistaken for hysteria or hyperventilation by the uninitiated and should only be made when decompression sickness is excluded.

Aseptic bone necrosis seen in deep sea divers and abalone divers is almost non-existent in altitude decompression sickness. This disorder has not been reported in USAF hypobaric chamber attendants over a 20 year period[26].

Treatment

In nearly all cases of altitude DCS recovery is rapid as descent is carried out to low altitude but the definitive treatment of altitude decompression sickness involves immediate recompression in exactly the same way as for diving decompression sickness. It is not within the scope of this article to present the treatment regimes provided. RAAF Medical Officers seek advice from hyperbaric medicine specialists when a case of altitude decompression sickness is suspected of requiring treatment after immediate supportive therapy is commenced.

Conclusion

The effect of hypobaric chamber flights is analogous to returning to the surface after surface supplied scuba diving and carries the risk of decompression sickness. The cabin of an airliner can be considered a hypobaric chamber and therefore divers returning by air increase their risk of developing decompression sickness if they have been pushing the limits of their tables. Medical practitioners need to be aware that altitude-induced decompression sickness, although well described in military aviation medicine, can occur in civilians and its onset may be significantly delayed. It is essential that the condition is recognised by a careful history and clinical examination and immediate arrangements made for urgent transfer to a hyperbaric unit.

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SOLO DIVER

Bob Halstead

As an active instructor for 18 years I have observed the buddy system in operation on thousands of dives. This also means that I have seen the buddy system fail on thousands of dives. I think that the idea of two divers sharing a dive and caring for each other is a wonderful idea but in practice it is an almost impossible achievement. We know what should happen, but how many times have you seen buddies that are incompatible, either through ability or interest, or where one is dependant on the other, or where the only sign of buddy activity is at the surface under the direction of the dive master, underwater the divers go their own way or are so far apart they are virtually alone? How many dives have you seen where the buddies have spent the dive looking for each other, yes and alternately coming to the surface (the most hazardous place to be)? How many dives have you seen spoiled because of the buddy system, and how many divers are put off diving because of the buddy system, either because they cannot find a buddy or they think about what the fact of the buddy system tells us about diving? Are we still “braving the deep”, is it really dangerous to dive alone?

I used to think I could do something about this and teach people how to buddy dive. It is a bit like marriage guidance. “Now Jane when you saw Jim signal that he was out of air and going to ascend, why did you chase off after the whale shark that was swimming past? What would a good buddy have done? Yes, I know you had plenty of air, but...”.

Now I have more than a sneaking suspicion that some of you would have abandoned Jim too, for that swim with the whale shark, for the lobster you have just spotted, for the photo that is just a moment away, sometimes just for the fact that you have still got half a tank of air left and do not want to come up yet. I say this with some authority since for the past two years I have been operating our liveaboard dive boat, “Telita”, and entertaining some of the world’s most adventurous and experienced divers. To many, if not most, of these divers, the buddy system is a myth. OK, I admit it, after thousands of dives escorting students on training dives, I just love to dive by myself. Some of my most memorable and joyful dives have been with my lifetime buddy, and fellow instructor, my wife Dinah. Sharing underwater adventures together is something that makes our love stronger and our marriage more fulfilling, nevertheless we both enjoy the occasional dip by ourselves. What I am saying is that buddy diving, like marriage, does not work for everyone all the time. People can, will and do solo dive, but are they trained for it?

Instructor organisations have a choice, they can condemn solo diving, and by doing so ignore what I believe to be a distinct trend in diving. Even a recent Skindiver editorial (famous for its conservative views) mentioned a solo diver being “with” someone in the boat. Or they can take a pioneering view and determine under what conditions solo diving could be accepted as a “safe” activity. I believe that for some people in certain conditions solo diving is a safe diving activity in the same way that I believe that some people will never be safe diving no matter how good the conditions, or their buddies, are. I find it easy to accept that it is safer for an instructor to dive by himself or herself than to be leading two students on an early dive.

There is something else here as well that is not so obvious. Teaching the buddy system teaches dependence. I know it should not, but it does. We call that negative incidental learning, and it is something that we are all warned about at Instructor Training Courses. Because so many of our training exercises involve the buddy, we install in the student the subconscious reasoning that they do not have to be as proficient as all that because they will always have their buddy to bail them out. No matter how much you teach that a good buddy team is made up of two equal partners, the system still says "Depend on your buddy". The danger in this is that when they eventually become separated from their buddy underwater, and they will, no doubt about it, they may be unable to cope. Without labouring this point too much, just imagine how students might perform if they had to perform one solo dive during the course. Pilots have to solo, do they not?

What I would like to see is a certification solo diver to appear somewhere after open water diver, as a regular course. It will have these benefits:

1. It will define those skills necessary, and the conditions necessary, for solo diving.

2. It will legitimise solo diving for those skilled and experienced enough.

3. It will clearly declare to the novice that it is desirable to have the skills of a completely independent diver.

4. It will show the novice diver that there are skills to master and experience to be achieved before they solo dive.

5. It will help to remove the false sense of security that the buddy system provides.

6. It will emphasise that the best buddy teams are made of two divers who are completely capable of looking after both themselves and their buddies.

7. It will concentrate the students learning on self evaluation, monitoring and rescue. (If everybody looked after themselves rescues would decrease significantly).

8. It will attract more people to diving and keep them in the sport longer.

9. It will make buddy diving safer.

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LETTERS TO THE EDITOR

DIVING DEATH STATISTICS

PADI Australia Pty. Ltd.
Unit 1, 1-7 Lyon Park Road,
North Ryde,N.S.W 2113
22nd May, 1989.

Dear Sir,

In a recent issue of *SPUMS Journal*, Monaghan[1] made use of statistical data published by PADI Australia[2]. Unfortunately, he has interpreted that data incorrectly.

The data in question — extended and updated — is presented in Table 1. At the time of preparing the data, the staff of PADI Australia were unaware of any reliable estimates of "Active Divers" in Australia, and even now is confident that no such estimate exists. Further, no studies on diver dropout rates had been conducted to enable calculation of such an estimate from certification figures. The other certification agencies were unwilling to share their figures with us. Thus, the only figures available for analysis were PADI's own certification figures.

Entry-level certifications figures were chosen as being indicative of growth in the number of active divers, even though an exact relationship could not be established; use of entry-level figures also avoided inflating the number of divers by double counting as this excluded continuing education figures. Data for the number of sport scuba diving deaths were obtained from *Project Stickybeak*.[3].

Then for each year, the number of deaths was divided by the number of PADI entry-level certifications and the result multiplied by 10,000 to calculate the number of deaths per 10,000 PADI entry-level certifications. The multiplier was chosen as 10,000 to yield results that fell in the range from zero to 10.

We made no attempt at direct comparison between the Australian data and that from the USA and Japan. Trends in each country were of more interest, in particular the downward trend in death rate in each.

Focussing attention on 1987, we see that PADI Australia certified 24,611 entry-level divers and there were 6 recreational scuba deaths — reported not calculated. Thus, we calculated the death rate of 2.4. To take this last figure, as Monaghan[1] does, and factor it by 33,023/10,000 to come up with the result that there were 8 deaths is getting the cart before the horse. (When I studied Chemical Engineering in the early 1960's, one of the basic tenets of model theory was that, if the model did not fit the observed facts, then the model was discarded or altered. To the best of my knowledge, there has been no change in this facet of model theory.)

If we accept that PADI has about 65% of the Australian market for diver training, then we can calculate that the death rate (per 10,000 entry-level certifications) in 1987 is:

$$6 \times 10{,}000 \div (24{,}611 \div 0.65) = 1.58.$$

TABLE 1

DIVING CERTIFICATIONS AND DEATHS, AUSTRALIA

	1984	1985	1986	1987	1988	5-Year Total	Growth Rate
Observed Data							
PADI Entry-Level Certifications	10,992	13,087	19,184	24,611	30,979	98,853	23%
Total PADI Certifications	14,295	17,842	25,780	33,023	40,736	131,676	23%
Recreational Scuba Deaths	10	9	9	6	4	38	-17%
Calculated Data							
No. of Deaths per 10,000 PADI Entry-Level Certifications	9.10	6.88	4.69	2.44	1.29	3.84	-32%

How meaningful is this figure? As an isolated figure it has very little significance. As one year's rate in a series of five with a monotonic decreasing trend, it has somewhat more significance.

In addition to the above, I believe that Monaghan may have assumed that the figures for new certifications in each year were cumulative. If so, this can be excused by the fact that the growth rate, as a proportion or percentage, in new divers in Australia is so much higher than in the USA.

There is little point in trying to draw comparisons between sets of data which are not consistent with each other, especially when there is doubt as to the validity of some parts of some of those data sets. At PADI Australia, we believe that the best estimator of death rate is one which uses the annual number of dives as the denominator. We recognise that this statistic cannot be calculated at present and probably never can be. We do believe, however, that surveys such as the one currently being conducted for the Dive and Travel Industry Association of Australia (DITAA), will enable us to move closer to that ideal.

James A. Morgan,
Internal Operations Manager.

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DACOR REGULATORS' AIR MAY SHUT OFF

RECALL ISSUED

Dacor Corporation has announced a recall of several of its regulator models. Because of a problem with the second stage regulator demand lever, the air supply could unexpectedly shut off. While not all regulators are affected, it appears that regulators purchased after October 1, 1987 are suspect.

Dacor learned of the problem in through a field report from Japan where a regulator failed in a swimming pool. Subsequent investigation revealed that some demand levers on their regulators do not have adequate corrosion resistance. Corrosion could weaken the level and cause it to snap, shutting off the air supply.

Dacor has sent shop posters to all of their retail customers, notified owners who have returned the warranty cards, and alerted the Consumer Products Safety Commission of the problem.

Owners of Dacor regulators should copy the serial number from their regulator, located just below the mouthpiece on the second stage, and call the toll-free number (USA 1-800/233-DIVE). Dacor operators can verify if your regulator is one of those affected by the recall.

If your regulator is affected, it should be taken to a Dacor dealer for retrofitting or sent to the Dacor Corporation: 161 Northfield Road, Northfield, IL 60093, Attention: R-89. If you include a note telling Dacor what the postage is, it will be refunded. There is no charge for this retrofit.

The regulator should not be used until the problem is corrected.

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The address of UNDERCURRENT is P.O. Box 1658, Sausalito, California 94965, USA.

THE WIDER WORLD

GLEANINGS FROM MEDICAL JOURNALS

The following articles have come to the notice of the editorial staff and these notes are printed to bring them to the attention of members of SPUMS. They are listed undervarious haedings of interest to divers. Any reader who comes across an interesting article is requested to forward the reference to the Journal for inclusion in this column.

COLD

Exceptional case of survival in cold water.

W.R. Keatinge, S.R.K. Coleshaw, C.E. Millard, J. Axelsson. *Brit. Med. J.* 18 Jan. 1986; 292. p. 171-172.

From the Department of Physiology, The London Hospital Medical College, London E1 2AD., and the Department of Physiology, Medical School, University of Iceland, Iceland.

Rewarming patterns in upper limbs. (Letter)

S.D. Livingstone, L.D. Reed, R.W. Nolan, S.W. Cattroll. *The Lancet* 25.10.86. p. 981.

From the Defence Research Establishment Ottawa, Department of National Defence, Ottawa, Ontario, Canada K1A 0Z4.

Mechanism of afterdrop after cold water immersion.

T.T. Romett, *J. Appl. Physiol* 1988; 65(4):1535-1538.

Summary

It was hypothesized that if afterdrop is a purely conductive phenomenon the afterdrop during rewarming should proceed initially at a rate equal to the rate of cooling. Eight male subjects were cooled on three occasions in 22°C water and rewarmed once by each of three procedures: spontaneous shivering, inhalation of heated (45°C) and humidified air, and immersion up to the neck in 40°C water. Deep body temperature was recorded at three sites: esophagus, auditory canal, and rectum. During spontaneous and inhalation rewarming, there were no significant differences between the cooling (final 30 minutes) and afterdrop (initial 10 minutes) rates as calculated for each deep body temperature site, thus supporting the hypothesis. During rapid rewarming, the afterdrop rate was significantly greater than during the preceding cooling, suggesting a convective component contributing to the increased rate of fall. The rapid reversal of the afterdrop also indicates that a convective component contributes to the rewarming process as well.

Key Words. Heat loss; conductive; convective; deep body temperature; rewarming.

Cold-induced pulmonary oedema in scuba divers and swimmers and subsequent development of hypertension.

P.T. Wilmshurst, M. Nuri*, A. Crowther, M.M. Webb-Peploe. *The Lancet* 14.1.89. p. 62-65.

From the Department of Cardiology, St. Thomas' Hospital, London SE1 7EH. *Present address Heart Clinic, Rawalpindi, Pakistan.

Summary

The effect of cold and/or a raised partial pressure of oxygen was examined in eleven people with no demonstrable cardiac abnormality but who had pulmonary oedema when scuba diving or surface swimming, and in ten normal divers. These stimuli induced pathological vasoconstriction in the pulmonary oedema group, nine of whom also showed signs of cardiac decompensation when so stimulated. The pulmonary oedema patients have been followed-up for an average of 8 years. Seven have become hypertensive. Except for the onset of lone atrial fibrillation in one normotensive female diver and development of Raynaud's phenomenon in a normotensive man, there have been no cardiovascular events and no deaths.

DECOMPRESSION PROBLEMS

Patent Foramen Ovale and Decompression Sickness in Divers.

Richard E. Moon, Enrico M. Campaoresi and Joseph A. Kisslo. *The Lancet* 11.3.89. p. 513-514.

From the Departments of Anesthesiology, Cell Biology, Medicine and Radiology, and Hyperbaric Center, Duke University Medical Center, Durham, North Carolina, USA.

Summary

30 patients with a history of decompression sickness were examined for the presence of patent foramen ovale by bubble contrast, two-dimensional echocardiography and colour flow doppler imaging. With bubble contrast, 11 (37%) of the patients had right-to-left shunting through a patent foramen ovale during spontaneous breathing. 61% of a subset of 18 patients with serious signs and symptoms had shunting. This number was significantly higher than the 5% prevalence seen with the same diagnostic technique in 176 healthy volunteers. The presence of patent foramen ovale seems to be a risk factor for the development of decompression sickness in divers.

Ocular fundus lesions in divers.

Philip J. Polkinghorne, Kulwant Sehmi, Maurice R. Cross, Darwin Minassian, Alan C. Bird. *The Lancet* 17.12.88. p. 1381-1383.

From the Departments of Clinical and Preventive Ophthalmology, Institute of Ophthalmology, University of London; and the Diving Diseases Research Centre, Fort Bovisand, Plymouth.

Summary

Retinal fluorescein angiography was used to examine the ocular fundi of 84 divers. The retinal capillary density at the fovea was low and microaneurysms and small areas of capillary nonperfusion were seen. The divers had significantly more abnormalities of the retinal pigment epithelium than a comparison group of non-divers. Furthermore, the prevalence of fundus abnormality was related to length of diving history. All observed changes were consistent with the obstruction of the retinal and choroidal circulations. Such obstruction could be due either to intravascular bubble formation during decompression, or to altered behaviour of blood constituents and blood vessels in hyperbaric conditions.

Eye tests reveal dangers of diving.

Lesley Newson, *New Scientist* 21.1.89. p. 33.

Decompression procedures imperil commercial divers.
New Scientist 4.3.89. p. 29.

Safety of Divers. (Letter)

Stephen J. Watt, John A.S. Ross. *The Lancet* 18.3.89. p. 613-614.

From the Department of Environmental and Occupational Medicine, University of Aberdeen, University Medical School, Aberdeen AB9 2ZD.

Neurological Decompression Sickness. (Letter)

P.T. Wilmshurst, J.C. Byrne, M.M. Webb-Peploe. *The Lancet* 1.4.89. p. 731

From the Department of Cardiology, St. Thomas' Hospital, London SE1 7EH.

Ocular Fundus Lesions in Divers. *The Lancet* 1.4.89. p. 731-732.

(Letter) P.B. James, Wolfson Institute of Occupational Health, University of Dundee, Medical School, Dundee.

(Reply) P.J. Polkinghorne, M.R. Cross, A.C. Bird, K. Sehmi, D. Minassian. Department of Clinical Ophthalmology, Institute of Ophthalmology, Moorfields Eye Hospital, London EC1V 2PD.

DIVING ACCIDENT TREATMENT

Should we stop teaching the head-down position for arterial embolism?

R. Kelly Hill, Jr., *NAUI Diving Association News.* Sept/Oct 1988. p. 33.

Dr. Kelly Hill's address is Medical Director, Department of Hyperbaric Medicine, Our Lady of the Lake Regional Medical Center, 7777 Hennessy Blvd., Suite 115, Baton Rouge, Louisiana 70808, U.S.A. Tel (504) 765-8976.

COURSES IN DIVING MEDICINE

ROYAL ADELAIDE HOSPITAL HYPERBARIC MEDICINE UNIT

Courses in Diving and Hyperbaric Medicine 1989

Basic Course in Diving Medicine

Content Concentrates on the assessment of fitness for candidates for diving. Health and Safety Executive (UK) approved course.

Venue and date
Royal Adelaide Hospital, Adelaide
11-15 September 1989

Cost $A 500.00

Advanced Course in Diving and Hyperbaric Medicine.

Content Discusses the diving-related and other emergency indications for hyperbaric therapy

Venue and date
Royal Adelaide Hospital, Adelaide
18-22 September 1989

Cost $A 500.00

Cost for both courses $ 800.00

For further information and enrollment contact

Dr D.F.Gorman, Director Hyperbaric Medical Unit,
Royal Adelaide Hospital, North Terrace,
Adelaide, South Australia 5000.
Telephone (08) 224 5116.

NEW ZEALAND

Course in Diving and Hyperbaric Medicine sponsored by the New Zealand Underwater Association

Basic Course in Diving Medicine

Content Concentrates on the assessment of fitness for candidates for diving. Health and Safety Executive (UK) approved course.

Venue and date
Christchurch
29 Sepetmber -2 October 1989

Cost $NZ 275.00

For further information and enrollment contact

Dr Mike Davis, Division of Anaesthesia,
Christchurch Clinical School of Medicine,
University of Otago, PO Box 4345,
Christchurch, New Zealand.

DIVERS ALERT NETWORK (DAN) 14th DIVING ACCIDENT AND HYPERBARIC OXYGEN TREATMENT COURSE

October 21 - 31, 1989 Palau Pacific Resort, Palau, Micronesia.

Course Description

This eight day course in Diving Accident Management and Hyperbaric Oxygen therapy is designed for physicians, emergency medical personnel, including paramedics and nurses. Portions of the course may be of interest to dive masters, dive instructors, and other non-medical dive related personnel.

The aims of the course are to provide the facts relevant to understanding the management of diving accidents, especially those bearing on the basic physics and physiology, and the subsequent treatment methods available.

The course format will involve morning and some afternoon and evening didactic sessions of lectures and case presentations. These will be supplemented by small group interactions with the faculty for direct question and answer sessions, review of case histories and some special video instructional tapes. Six afternoons will allow spectacular two tank diving.

All proceeds from the Course go to support the Divers Alert Network (DAN).

Faculty

Drs. Peter Bennett, Carl Edmonds, Des Gorman and Yancey Mebane.

Course charge

Payable to **Duke University Medical Center**.
$US 425 **(before August 21, 1989)**
or $US 495 thereafter.

Register by sending cheque with name, address and telephone number to:

Office of Continuing Medical Education
Box 3108
Duke University Medical Center
Durham, North Carolina 27710
USA.

For **accommodation** and travel from USA contact:

"Duke/DAN Palau Course"
International Diving Expeditions
11265 Knott Avenue
Cypress, California 90630
USA
Telephone: (714) 897-3770

MEETINGS

THE 1989 ANNUAL CONFERENCE OF THE NEW ZEALAND CHAPTER OF SPUMS

will be held at Whangarei
21st to 23rd October 1989

For further details contact

Dr Beris Ford,
19 Rust Avenue,
Whangarei,
New Zealand.

EUROPEAN UNDERSEA BIOMEDICAL SOCIETY

XVTH ANNUAL SCIENTIFIC MEETING EILAT, ISRAEL, SEPTEMBER 17-23, 1989

PROVISIONAL LIST OF TOPICS

1. Breathhold diving
2. Deep sea saturation and mixed gas diving
3. Decompression sickness
4. Diving for the disabled - medical aspects
5. Effects of pressure
6. HBO therapy
7. HPNS
8. Immersion
9. Nitrogen narcosis
10. Oxygen toxicity
11. Preventive diving medicine (education)
12. Seasickness
13. Technical and therapeutic instrumentation in the hyperbaric chamber
14. Unconsciousness in diving

PANEL DISCUSSIONS

HBO Therapy - Specific Indication and the Correct Oxygen Dosage
Different Therapeutic Methods for Severe Type II Decompression Sickness

Meeting Venue

The King Solomon Hotel, Eilat is the headquarters of the XVth Annual Meeting of the European Undersea Biomedical Society.

For Further Information Contact

XVth EUBS Meeting
P.O. Box 983
Jerusalem 91009
ISRAEL.
Tel. 972 2 533717; 527335,
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ARTICLES OF INTEREST REPRINTED FROM OTHER JOURNALS

READERS REPORT ON DIVE COMPUTERS
Plenty of Problems, But Not the Bends

If you own a dive computer, you most like would just as soon dive without fins than go diving without your computer. Because of their ease of use, divers don't have to remember the tables or even compute their own surface intervals, today's divers in increasing numbers are relying on meters for every aspect of their diving.

In our July 1988 issue, we included a questionnaire on decompression computers asking readers for their comments. Nearly 1,000 readers responded, from which we obtained 905 complete responses for eight computers.

	Number	%
Orca Edge	389	43
Orca Skinny Dipper	279	31
Suunto	84	9
Oceanic Data Master II	59	7
Beauchat Aladin	53	6
USD Data Scan II	16	2
Dacor MicroBrain	13	1
Sherwood Sigma Tech	12	1

Some care must be exercised with this data. When dealing with the small bases of responses for Data Scan II, MicroBrain and Sigma Tech, any conclusions drawn may be out of proportion to reality. However, if the raw data for Data Scan is added to the data for Data Master (basically the same computer), and the data for Sigma Tech is added to that of the Skinny Dipper (basically the same device), one can get a more accurate picture of these computers. MicroBrain, however, only had 13 responses and is not comparable to any of the other meters.

Orca Industries dominates the market, according to the responses from our readers. The Edge accounts for forty-three percent and the Skinny Dipper for thirty-one percent of the meters in use by our readers, or a total of seventy-four percent of the meters owned by our respondents. This probably reflects the length of time that these computers have been available.

Validity and Reliability

There are two fundamental issues at stake in the analysis of any device, its reliability as a mechanical and electronic unit and the validity of its tables in preventing decompression sickness.

Until recently, little data was available on the validity of dive meter tables. At the end of last year, however, DAN released results of a study showing that bends occurred on approximately two percent of the dives. Our readers have been more fortunate. Although fifteen respondents (1.6%) had been bent while using their meter (in two cases, more than one device) this figure represents something less than 1/100 of one percent of the dives. These are the devices they used: Sigma Tech (1); Aladin (2); Edge (8); Skinny Dipper (5); Suunto (2) and no reported bends for the Data Scan II, Data Master II, or MicroBrain.

This is what the divers who got bent said about their incidents:

A San Diego diver was using a Suunto and said that "it was in its error mode, so it wasn't functioning as a computer". He reports that he "usually takes it to its limits". This diver is no lucky fellow. He reports another incident using a Beauchat and a Skinny Dipper, which "shut off during the first of two dives. I used it along with a Beauchat on the second dive (the Beauchat was used on both)". He said "I followed a 20-minute dive to 253 feet (+ 40 min. decompression) with (after 3 hours) a non-decompression dive (160 feet for 8 min., 80 feet, 20 min.). One hour after surfacing, I had decompression sickness, blockage of artery supplying nerves to inner ear".

A physician from Miami, used the Sherwood Sigma Tech and made three dives (80 ft., 80 ft., and 55 ft.). After vomiting and weakness a brain stem bubble was diagnosed and he recompressed in a chamber. He said " I used to dive near the limits until the CNS event", but now he only uses the meter as a "backup to the Navy tables".

A Delaware diver reports that he "had skin bend after doing a second decompression bounce dive following the first decompression dive, back to back, with no surface interval". He was using a Skinny Dipper with a Beauchat as a backup.

A Dallas diver says that "Twice I have been to a chamber due to bends-like symptoms (tingling and numbness and pressure). Both times they felt after treatment that although symptoms resembled bends, it probably wasn't the bends. Symptoms remain after treatment. They come and go periodically. Although diving may be involved, it's not the bends. My dive profiles were even conservative for the Navy tables. I decompress on every non-decompression dive and didn't do any decompression dives. Problem still undiagnosed". She uses a Skinny Dipper as "backup to Navy tables. If I have been careful to slowly work up from deep to shallow, I sometimes stay longer than the Navy tables to decompress even though it hasn't been a decompression dive".

"The first time I used the Skinny Dipper", reports a South Carolina diver "I was wreck diving. Both dives were within the limits set by the Skinny Dipper. The first dive was within the Navy tables. The second dive was slightly over. I did a 5-minute safety stop. I got bent the next day".

A Colorado diver stated "My fault. I wanted to take the computer to its limit".

A Maryland diver was using an Edge "on a planned decompression dive. The first dive was to 130 feet for 21 min. bottom time using computer to do progressive decompression. Stayed five feet below ceiling indicated at all times. Hung additional five minutes on first dive. The second dive was to a maximum depth of 133 feet, with a bottom time of 28 min. Again did progressive decompression, allowed additional two minutes at ten feet for hang. Wasn't bent badly but did make trip to the chamber at the University of Maryland".

A female diver from Honolulu said that "It appears that my physiology is such that by running my diving close to the extreme margin of Edge safe diving, I subject myself to more of a chance of becoming bent than by using the Navy tables. Bent once last year in Palau using the Edge and discovered when I stopped using it my almost permanent pack pain while repetitive diving went away".

A diver from Florida was bent "when surfacing from an extreme cold water rescue and recovery dive. I, however, feel the reasons are totally physiological, not to be tied to the Edge. After the incident, which was mild to light in nature, I got in better physical shape and no other incidents in cold water happened".

A Connecticut diver used the Edge and reports that he has been bent "three to five times. Minor tingling in the hands and arms; pain in the shoulder; blurred vision; red and itching in the midsection".

A Pennsylvania diver reports that her Edge "said I had hours, so I surfaced. I got two hits in the spine and experienced temporary partial paralysis". She had made three dives with it.

Last July a diver from Florida got bent after "a third dive to 80 feet. I usually make a safety stop. This time I did not, due to building weather. I was still within my Edge limits. After five minutes I had shoulder pain. Most of pain went away during 1-hour boat trip home. At dock, physical exertion brought pain back big time, so I went to the chamber at Gainesville, Florida".

One reader, who prefers to remain anonymous, said that "In the Maldives in 1985, my Edge suddenly went black after two dives to the 40-60 feet level. The divemaster prescribed 120 foot afternoon dive which I didn't want to miss so I went without the Edge. No problem. But went on a 'shallow' evening dive and one hour post-emergence developed constricted visual field in left eye, confusion. Lasted one hour, no sequelae. I think I had transient decompression sickness, mostly my fault as I overdid it that day".

Although our survey is not scientific, the incidence of bends reported appears low for so many divers and dives. They do suggest a couple of conclusions. Unique diving profiles can be troublesome and should be avoided by the careful diver, but even the most cautious diver may be susceptible to a bends hit. Decompression computers offer no guarantee; the physical makeup of the individual, age, weight, general condition, contributes significantly to the likelihood of getting bent.

Other Problems

The accuracy of the time and depth indicators in the computers seems to be vastly superior to mechanical devices. For example, tests of depth readouts of many of these devices show a consistent error rate of less than two feet, while mechanical gauges have been found to be off by ten feet or more. However, our questionnaire did uncover what seems to be a high number of other problems. Our readers reported a variety of malfunctions during the dives, which will be discussed in greater detail in subsequent parts of this article. In the order of most problem mentions to least mentions are:

Sigma Tech	33%
Skinny Dipper	28%
Aladin	26%
Edge	24%
Suunto	17%
MicroBrain	15%
USD Data Scan II	13%
Oceanic Data Master II	12%

These numbers seem very high for such expensive, critical products. In subsequent issues we will look at problems of specific meters.

Dive Without Computer Backup?

With all these potential problems, our survey discovered that some divers shun backup devices such as depth gauges and watches and rely *entirely* on their electronic computers. Although 88 percent of the divers use some additional backup equipment, 12 percent use only their computers. Several divers indicate they have supreme confidence in their computer.

A doctor from Maine says, "I am confident in my Skinny Dipper and am always well within the limits of decompression". Another diver says, "I fully trust the computer, it's far more accurate than the old depth gauge. If there was a discrepancy between the two instruments I would rely on the computer unless there were other reasons to believe the computer was malfunctioning". A NAUI instructor from Tampa, says: "I know many serious divers who have used an Edge for years and they have given me no reason to worry about a backup". Many divers say if there is a malfunction, they will simply abort their dives for the day.

Some readers say they use no backup because dual systems are complicated or incompatible. One says a computer and backup are "too confusing; use either one system or the other".

A number of people who dive without redundant devices confess that they rely on other divers for backup. A woman diver from Maryland says: "I know about ten people with Edges who have never had any problem, so I trust it more than I should. My backup is my buddy's Edge, casual backup, that is, since buddies change". Another reader says, "one member of our dive group uses conventional gauges and we check the readings with our computers". Another writes, "How far does safety go! My buddy has a set of gauges to back me up".

In addition to those who carry no backup, we would estimate an additional fifteen percent of the respondents used only a watch (without a depth gauge) or a depth gauge as the sole backup. That means that as many as twenty-five percent of the divers using computers are not fully backed up. One of these writes "I use a watch only, just to note the time in and out. I don't use any other devices because their functions are not critical enough (as opposed to an octopus) to warrant redundancy. If the computer fails I would immediately abort the dive". And some people say that "I wonder why I bother to carry a watch and depth gauge? I can't go back to the tables and would have to stay out of the water 24 hours if my Skinny Dipper fails".

The answer to those who wonder why they need to carry a backup watch and depth gauge is based on what action they need to take should their computer malfunction at depth. Suppose you are on your second dive of the day after several diving days. You have been in the water for awhile, you are quite deep and your computer, all of a sudden, has no reading for you. You must exit. You need to rise at the rate advised by your own computer's instructions, 40 feet per minute, 20 feet per minute?, and you probably ought to stop at one or more depths to blow off the nitrogen. Would not a watch or a bottom timer and a depth gauge be essential to a safe ascent?

At least seventy-five percent of the respondents dive fully backed up, but few with systems so redundant as a Springfield, New Jersey wreck diver who reports that he uses "three depth gauges (two bourdon tubes for depth indication, one capillary for decompression stops), one wind-up bottom timer, two navy tables (one on my light, one in my tool pouch). I use the Edge as a backup to the Navy tables. The major use is to guide my ascent, the secondary uses are surface interval timing, maximum depth indication, and backup bottom timing".

A diver from Annapolis uses a depth gauge and bottom timer: "Orca told me that if you can verify your depth and bottom time to be correct, it is almost impossible to have a computation failure". A diver from Sinking Spring, Pennsylvania backs up his Skinny Dipper because "I don't have full confidence that the chips in my Skinny Dipper are more stable than my home computer which occasionally goes wacky and needs to be reset". A woman from Indiana says, "If I forget to turn on the Dipper I still can carry out my dive".

Some people have had problems that confirm their need to carry backup. A Pennsylvania pair says they have "taken the Skinny Dipper on two live-aboard trips and it failed us both times the first day of diving. We cannot rely on it". A diver from Dayton, Ohio was diving at the Brac, when one of his buddies' computers "maxed out at 126 feet while his Dacor gauge was pegged at 200 ft. Turned out the computer was grossly miscalibrated.

The questionnaires reveal that many people use mechanical backup devices because they purchased them prior to buying a computer and continue to use them out of habit. A Charleston, South Carolina diver writes, "I continue to dive with my console probably because I already owned it. But, how much backup is necessary? I never used a back up for my gauges in the past. I have no qualms about relying on my computer".

A number of people indicate that they are using a second computer as backup, in some cases one they originally purchased and replaced with a model they like better. One fellow who reported that he has been bent uses a Beauchat Aladin as backup to his Skinny Dipper and an "Edge is standby backup if either the Beauchat or Skinny Dipper fail". Just like backing up a computer with the Navy tables, using a different computer for backup means falling back on different tables as well.

Finally a diver from Boca Raton, Florida, gives the most succinct answer to our question about whether he dives with backup devices: "Hell yes, I do. I read your "Bendomatic Computer" series and the 'Why Divers Die" articles".

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THE EDGE
THE SPORT DIVERS' FAVOURITE
But Just How User Friendly?

Last (Northern) summer (1988) UNDERCURRENT conducted a survey about dive computers and received more than a thousand responses. This is the report on the Edge, and in the subsequent issues UNDERCURRENT will report on other models.

The oldest of modern dive computers, the Edge is owned by nearly 43 percent of the respondents in our study.

The Edge and its little brother, the Skinny Dipper, are the most loved while, at the same time, are not without their problems.

Ninety percent of the Edge owners report they are satisfied with their computers, making the Edge the leader in the satisfaction derby. (Eighty-four percent is the average of all *UNDERCURRENT* computer owners.) Seven percent said they would not buy one again and three percent "don't know".

The original Edge units, Orca's Paul Heinmiller told *UNDERCURRENT* , came with the "version 3" program. This program was later modified to include an ascent rate indicator, a change in temperature readout from centigrade to fahrenheit, and modifications in the slow tissue limits. Those units that have been upgraded to this version are called "version 4". Those units that come new with this program are "version 5". The cost of an upgrade is $85, which includes full servicing. When the unit is turned on, the version number will light up just below the whale logo.

The obvious advantage the Edge has over its competitors is the graphic display in which 12 pixel bars, representing 12 body tissues, approach a decompression line as the diver approaches decompression circumstances. That feature, above all others, is perhaps why divers still choose the Edge, a heavy and cumbersome device compared to newer computers. As a Montclair, New Jersey, diver simply says, "I'm a graphic diver".

Following the Pixels

Most divers never let the pixels hit the no-decompression curve on the face of the meter. For example, a diver from Mariette, Georgia, says, "I dive 'The Gap' not the Edge. In other words I try to leave a two pixel gap between all tissue groups and the decompression line". A diver from Illinois goes further. "I watch the pixels fall in and make sure I never hit the line. I also watch the scrolling information. I leave 3-5 minutes before I'm maxed out and ascend per the Edge guidelines and take 5 minutes at 10 feet for repetitive dives."

Some divers let the pixels cross the no-decompression line, then bring them back at shallower depths. For example, two divers from Bethesda, Maryland, say, "on dives below 100 feet we may let the five and ten minute half-time pixels go beyond the edge but then ascend to shallower depths until all pixels are at least one above the edge. Ascent rates are never faster than 30 feet per minute and we always make a safety stop of five minutes at five meters on dives below 60 feet and two minutes at this depth (minimum) on shallower dives".

For some people, the graphic display is essential to their underwater pleasure. "Because of the graph, even with aging eyesight like mine, while narced, I can still read it", says a reader from Kailua-Kona, Hawaii. And Alan Baskin, who operates Baskin in the Sun in Tortola writes: "I like the ability to monitor the 12 tissue loadings and unloadings", which pretty well sums up why many divers prefer the Edge. The Edge is just a little more fun to use.

The functioning of the graph has caused a few minor problems for Edge divers. One reported that a row of pixels "just disappeared" while diving. Another said "The Edge said I was ascending too fast, and when I surfaced it said to 'descend now'. My ascent had been *unbelievably* slow and I knew from the pixel on the bottom that I had extra bottom time. I continued to surface". And a third diver says, "It was adding pixels for no apparent reasons. I've since had it upgraded and it's behaving fine again".

Other divers, especially working divers, prefer the Edge over many competitors because it permits decompression diving. A sport diver from Camarillo, California, says "I like the decompression dive information. I've never taken the computer into a decom situation, but if it happens the data may help to prevent problems".

The Edge has not been without its own problems. Of the 389 users who reported to *UNDERCURRENT*, 94 (or 24%) reported that their computer has malfunctioned one or more times during a dive. In some cases it was due to diver error (made easy because of the case design) while in other cases the device itself was faulted.

Disappearing Display

A number of divers report that for no apparent reason, their Edge just stopped reading out. Says a woman diver from Mission Viejo, California, "The computer shut off as I reached the bottom of my first dive of the day. I came up at once and the computer came on again. I changed the battery to the other wires and was OK. Another says, "the Edge shut down then turned back on. It was in its holster so I didn't do it. The dive was aborted and all diving was resumed the next day".

Of course it's impossible to determine the precise reason for the failure in these instances and if anyone experiences such a problem the Edge ought to be returned to Orca for analysis. The Edge switch, however, is sensitive to magnetism; it can be turned off accidentally if brought near the magnets such as those in the magnetic switch in the Pelican Light. But the battery compartment, itself, has been the Achilles' heel of the Edge.

The Edge is powered by a nine-volt battery inserted in a chamber on the back of the device. Inside are two sets of terminals, so when one battery is dying (a signal on the front will indicate a low battery) another may be installed to keep the device running while the dying battery is disconnected. Alkaline batteries power the Edge for up to 100 hours, while the new lithium batteries give 200 hours, or eight days. Nonetheless, because the diver must change the batteries himself (unlike many of the newer models on the market which have with battery lives up to five years), there can be problems. Dozens of Edge users reported their battery compartment had flooded for one reason or another. Since it often takes a while for the batteries to short out, a dive can be underway before the display goes blank.

Batteries should not be stored in the computer. Heinmiller told *UNDERCURRENT* that one Edge owner put his away for two years with the alkaline batteries intact. They leaked and corroded the case. The cost of repair fell on his shoulders, not on Orca's as the user demanded.

User Unfriendly

As did many readers, a diver from Naperville, Illinois admits his own error: "I improperly installed the O-ring and it flooded. I stayed shallow and relied on buddy's Edge for the remainder of that dive". A Miami diver says that "the battery compartment flooded because I did not tighten the screws enough. I cleaned the computer and started it up the next day, after a 14-hour surface interval".

When the display goes off, divers select a variety of ways to conclude the dive. When the battery compartment flooded, one "finished the dive well within time remaining shown last time checked while working". Another says he "remained on the original dive plan and proceeded to utilise the Navy tables". A third said "when it flooded it stopped working on a first dive. Since it was not a repetitive dive, I surfaced before reaching 33 feet and started over". A San Antonio diver reports that the display "went blank at about 70 feet at the end of the dive. I notified my buddy and we agreed to ascend to 20 feet and finish the dive".

If your Edge battery compartment does flood, all is not lost, as a diver from Indianlantic, Florida, explains: "I flooded my battery compartment by not properly seating the O-ring. Upon return to boat, rinsed and blow dried the unit, replaced the battery and used it successfully for duration of trip. I've since had it factory reconditioned".

Orca struggled with the O-ring leakage problem from the beginning and, about a year ago, produced a new cover plate to which the gasket is attached. This "high performance gasket", as Orca calls it, is available for $20 from Orca and can be used on all previous models.

Not a Snap

Inside the battery compartment, the snap-like battery connectors have been problematical, as one diver found out. "During descent on a 200 foot dive the readout went blank, then went back on. I used my backup depth gauge and watch to complete dive. It turned out that the battery connector was loose." Another says that the "battery contacts bend and can make poor contact. They must be checked regularly".

Richard Nordstrom, President of Orca, told *UNDERCURRENT* that they attempted to use "off the shelf connectors, but they didn't work well". Orca has replaced them with battery clips, which they will install in older models for $25.

Screw Short

"When I changed batteries during my dive vacation, I have shorted out my program. It's very easy to do", reports a diver from San Francisco. Several other divers have had the same problem. One from New York City says he "shorted contacts while changing battery and lost all information and had to wait 24 hours for next dive". And a Houston diver says quite succinctly, "Poor design!"

Nordstrom told *UNDERCURRENT* that part of the shorting problem is due to a small screw in the battery compartment, which has been taken out of newer models. Divers with older models need to be careful to keep the connectors away from the screw.

A life-supporting device needs to be designed to minimise human error, and it's here where the Edge falls short. "Advanced electronics and primitive mechanics", says one reader. The result is that many people inadvertently goof, losing the Edge's memory. A diver from Columbia, Maryland, admits to an error that more than one Edge user has experienced. "I was replacing the battery with an identical one. I got confused and left the old battery in place. Ran out of power in the middle of my second dive."

Perhaps the woman diver from Honolulu speaks most eloquently for all those who have had these problems. "The Edge is one son-of-a-bitch to change batteries on." She has "someone else assist so as not to lose my readings".

Who pays for a computer stopped by a flood? A diver from Del Mar, California, says that her "battery compartment flooded and it was fixed at no cost by Orca". But two divers from Columbia, Maryland, said that after a "malfunction of O-ring on their first dive it cost $65 for cleaning battery compartment. Not very pleasing".

Flipping the Switch

Another problem is caused by inadvertently flipping the on/off switch, causing the stored dive data to be lost. A diver from Oak Forest, Illinois, says that "many times on land the switch will accidentally go off, destroying the data on past dives. Once the switch flipped off during a dive". Another from Tampa says that twice he "removed the unit from the holster and the switch got bumped to the off position". Another says "the on/off switch was accidentally raised up and my accumulated data was lost. There should be a locking mechanism as the switch need not be raised too far to cause shut down". A woman diver from Allentown, Pennsylvania, has her own solution: "Twice during one week when putting it in the holster, the on/off switch got caught and the Edge was turned off. I stayed out of the water for over 12 hours and watched my slow tissue profile. I now tape the switch in the on position when I turn it on." Another reports that "I lost my Edge memory when the switch was accidentally turned off by curious divers, between dives".

Nordstrom indicated that Orca redesigned the holster last year to help alleviate some of the problem (it can be ordered for $20). Some minor problems can be corrected when the unit is serviced, but if the switch itself is faulty the repair tab will run $66.

The Electronics

It's interesting to note that few incidents can be attributed to the electronic technology of the Edge. Where the first generation of meters in the early 1970s proved electronically faulty, the real breakthrough of the Edge has been that it has solved most of those problems. Only six users reported such technical problems. A New York diver says the "transducer (depth gauge) went wrong by about 20 feet (at 100 feet) so that computer read 80 feet rather than the actual 100 feet. *Nasty* malfunction as the unit kept on functioning with the false reading". A dive shop owner has had the same problem. "The depth transponder malfunctioned. Dive was aborted and I rented a unit for remainder of the trip. Repairs were quick and at no charge." A Boynton Beach, Florida, diver says that "Oil filled depth transponder leaked. This made the depth gauge read about 20 feet less than actual depth. Computer calculated based on erroneous input. Fortunately I knew the reef well and realised depth was way off. I also knew approximate profile and never was endangered although I could have been". A physician from San Luis Obispo, California, had a similar problem. "The computer's depth gauge was 12 feet off suddenly (I always compare my readings with other divers and with my separate depth gauge). When I came up another diver's Edge said we were OK, but mine read 12 feet deeper." And a woman diver from McLean, Virginia, said that "the Edge told me I was in decompression when that wasn't possible. I've since had it upgraded to the V".

Orca's Paul Heinmiller told *UNDERCURRENT* that one batch of Edge cases were not made to specification, so to use the cases modified transducers were manufactured to fit them. They turned out to have faulty seals.

A few readers reported that their Edge gave them too short a notice when the battery ran low. "I never had a warning of low battery" says one "this was a shallow dive and I made sure I stayed less than about 40 feet." Another says, "I got a battery 'lo' lite and within 10 minutes computer face was blank (book guarantees 4 hours after 'lo' lite comes on)". And a diver from Herndon, Virginia, says that he got "no 'low battery' warning when using a lithium battery". Says a diver from Colorado, "There is not enough time indicating a low battery. When the indicator does begin, and it's at night, you will lose all information by morning". Another diver said, "The low batter indicator has never worked".

We reported these incidents to Nordstrom, who said that the only reason he knows that divers would not get a four hour warning would be if they had used a carbon battery, which is not as strong as the preferred alkaline or lithium batteries. If a diver has such a problem with his Edge, he should return it for servicing. Of course, it is true that if the Lo indicator comes on during the night or on a day when you are not diving, one will miss it. A diver has to keep track of the number of hours his battery has been working and change it before the "lo" indicator.

One diver finds that the face "fades somewhat when the unit gets cold and has a weak battery. It returns to full contrast when rewarmed or new battery is installed". Alkaline batteries, according to Nordstrom, are more susceptible to cold. In extremely cold water lithium batteries should be used and they should be changed more frequently.

A few Edge owners such as a doctor from Oklahoma City reported that the "script began to fade after several years. I sent it back and Orca promptly repaired and returned it".

Broken Screws

There were other annoyances. Several readers complained that the screws to the battery compartment broke off too easily when being tightened. In three cases, the screws could not be removed from the case and had to be returned to the manufacturer for repair. One reports that "a screw holding cap on broke while changing batteries. Had to return my Edge and have pressed in threads removed and replaced. This has happened twice. I now carry a spare cap and screws", he says. "A $600 machine with 5-cent knurled nuts that pop off when tightening", says another

Nordstrom says that the screw has been beefed up to increase strength and the slot in the top has been made smaller so that only a dime will fit. Nickels and quarters provide too much torque. But the screws are fragile; they should be washed in fresh water, lubricated with silicone grease to prevent corrosion, and tightened with care. And extras should be carried: $2.50 a pair from Orca.

Four users reported that the glass fogged up in colder water or when passing through dramatic thermoclines. Three readers commented that the knob hose clamp on the holster that attaches to the hose comes loose too easily, risking loss.

Although the steel case is solid and strong, one must remember that the Edge is still a delicate instrument and handle it with care. Another doctor from Oklahoma City says his Edge "once lost its repetitive dive data following a hard blow by a tank immediately before a dive". And a Daly

City, California, diver said, "I accidentally dropped the Edge. On the subsequent dive it registered my depth as too shallow by 7-12 feet. Which I confirmed with my other depth meter as well as my buddy's. I did a conservative dive and then used the tables for the rest of the trip".

Finally, the biggest thing going against the Edge is its size. It's heavy, a pound and a half, and, compared to the wristwatch-sized Suunto, enormous: about the width, depth, and half again as long as a pack of cigarettes. Many people indicate that their primary reason for switching from the Edge is to get a less bulky device, which is exactly why its little brother, the Skinny Dipper, sells so well. The Dipper does just about everything the Edge does, without the graphics and without the bulk.

Even so, as we reported earlier, ninety percent of Edge owners would buy it again. Many who wouldn't will remain with Orca and switch to the Skinny Dipper. Says one diving wife: "I'll probably buy a Skinny Dipper and give my husband the Edge".

Let the users explain why the Edge remains at the top of their list.

"I love the graphics and still consider the Edge (and Orca) to be state-of-the-art and most experienced."

"I know some people who have pushed it to the limits and they have never had any difficulty with it. They have done eight to nine dives in one day because of their job."

"I'm confident about the conservative algorithm and feel the slow ascent rate is important. All the recent table revisions and new experiments seem to support the sound basis of this product."

"High confidence level has been established by being used the longest. The new brands haven't put the time in."

"It's the best on the market with the greatest amount of research behind it."

"User friendly."

"It's the best I've seen."

NOTE

Initially, Orca did not have a recommended servicing period for the Edge. But they have found that salt can build up to the point that it could cause the case to leak. Therefore, Orca recommends that Edge users should have the unit serviced annually. For $69.95 the unit gets cleaned and calibrated and screws and seals get replaced. For more information about the Edge, for repair, or to purchase parts or upgrades, contact: Orca, 10 Airport Way, Toughkenamon, PA 19374. 215/268-3164 or FAX: 215/268-2267.

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SKINNY DIPPER PROBLEMS SOLVED?

The Skinny Dipper dive computer, manufactured by Orca, was introduced in May, 1987. Thirty-one percent of the 904 divers sending us valid questionnaires owned Skinny Dippers; 43 percent owned the Edge. In 1980, the Skinny Dipper began to be marketed by Sherwood as the Sigma Tech. We received only 12 responses from users.

Although it uses the same algorithm as the Edge, the Dipper differs in that it does not graphically display decompression data with pixels and a decompression line. Only numerical data is displayed (but not, as with the Edge, the amount of time required at a decompression stop). By eliminating this feature, and incorporating the electronics in a plastic case, Orca has produced a computer that, when compared to the Edge, is significantly smaller (about half the volume), lighter (5.5 ounces versus 24 ounces) and less expensive ($420 list compared to $625 list), while retaining the basic characteristics.

The result is that a large number of sport divers find the Skinny Dipper fully satisfactory as their primary computer, while others use it as a backup for their Edge. In fact, that is exactly how Karl E. Huggins, the father of the Edge algorithm, uses the Dipper, as he reported to *Undercurrent* on the questionnaire he submitted.

The Leaky Battery Compartment

The Skinny Dipper case and battery compartment design is different than the Edge. Unfortunately, like the Edge, it too has been a cause of leaks resulting in computer malfunction. In fact, slightly more than one-third of the respondents to our questionnaire indicated that their Skinny Dipper had flooded during a dive. Several readers reported that after they sent their Dipper to Orca, the repaired or replacement unit flooded as well.

To solve the problem, Orca has made many changes in the Dipper, including retooling the battery door and the case. At a seminar on the Orca in Oakland, California, recently, Orca Director of Engineering, Paul Heinmiller said, "we feel secure that the leaking problem is resolved at the moment". He said that only five of the units manufactured after September, 1988, have been returned. Orca's Jim Fulton told us that no Dipper manufactured after October 1988 has been returned.

Readers report that the leaking is sometimes little more than a few droplets of water entering the case. But it is enough to cause problems. In some cases the computer malfunctions or stops operating during a dive. In other cases, the low battery indicator suggests the batteries are fading far earlier than they should. The water shorts the batteries and sometimes corrodes them, causing battery acid to leak.

The leaks often occur on the very first usage, at times rendering the Dipper useless for the remainder of one's trip. One respondent said, "I purchased new Skinny Dipper for use on Honduras vacation. It worked properly on the first dive, but registered 'lo lo' prior to the second dive. I had to discontinue use for the remainder of two-week vacation".

The Dipper has three low readings. On the surface, a flashing "lo" indicates the batteries are beginning to go, but the unit still functions normally; "lo lo" will flash underwater when the batteries need replacing. There are still several hours of operation left and no information is lost, but the two warning lights for the ceiling alarm and the ascent rate no longer blink to conserve energy. "lo, lo, lo" indicates the battery power is insufficient and the computer locks. The special lithium batteries provide about 500 hours of power under normal circumstances. When they are changed, no data is retained.

In some cases the Dipper could be put back into service by the users. A Houston diver reports: "I rinsed out the battery compartment, blew it dry with tank air, inserted the batteries, blew it dry with tank air, inserted the batteries, greased the o-ring and turned it back on. It worked fine for the next six days after flooding on the very first dive".

Often, users put the onus on themselves for not applying enough silicone grease or for failing to put the battery door on properly. (It seems that we divers have been inculcated with the belief that if anything leaks underwater it is our error and never the fault of the product.) In most cases, it seems, the problem lies with the Dipper design itself.

Virtually all users of failed Dippers eventually return the computer to Orca. Our readers generally report satisfaction with Orca's response, saying they are quick to repair the device and return it at no charge when the product is under the two-year warranty.

But even these repairs, report several readers, did not solve their problems. "I bought the Skinny Dipper for my boys", says one diver from Corpus Christi. "I have an Edge and the Skinny Dippers were less expensive and had the same program. I have been very disappointed. We have had problems from the first use with flooding. They were returned and tested and on first use flooded again." A Seattle diver said: "The second Skinny Dipper lasted less time than the first so they took it back too, and rebuilt the housing".

So What's the Problem?

Orca staff have always been willing to discuss openly with *Undercurrent* any problems they have faced. Orca President Richard Nordstrom said that it has taken quite a while and great expense to pinpoint and resolve the problems with the leaking Skinny Dipper. First, there was a depression in the battery door compartment that allowed water to seep in. The depression was so slight that it could not be seen and could not be measured with calipers. It was only discovered once they put the units under an optional scanner.

Second, glue used to fasten the power feed lines was also intended to seal. The glue adhered, but it did not seal. They have changed glues and now also seal the units separately.

Third, to eliminate or minimise the battery door problems, Orca went to a quad ring, rather than an O-ring. This can be compressed at several points and allows for better dispersion of the silicon grease, creating a better seal.

Fourth, Orca redesigned the battery doors and, last September, sent the redesigned door (coloured black to distinguish it from the original white doors) to all owners of record.

But even that redesigned battery door proved not to be the final solution. A PADI instructor from Kingsport, Tennessee, writes, " received a new black battery door and on/off switch. Previously, I had used the Skinny Dipper on more than 75 dives without incident. I used the new door at Orca's urging. Suddenly, with the O-ring properly lubricated and properly installed my battery compartment flooded on five consecutive dives to a maximum of 68 feet. I am replacing my 'new' part with the 'old white door'."

Nordstrom said they discovered a problem due to variances in the cooling of the plastic case or door after injection molding. There can still be tolerance variances of 1/1000 to 2/1000 of an inch, in some cases just enough to permit water to enter the chamber.

Nordstrom said that if a diver today returns a flooded Dipper, they replace the entire case as well as repair the mechanism. "This is something that we have to do. We are in business for the long run."

It seems remarkable that the Dipper has remained on the market and sold well with such a high rate of flooding and malfunction.

Has the Skinny Dipper remained popular because dive shops do not apprise the consumer of the return rate?

Is it because many people presume the problem is their fault; that they did not seal the O-ring properly?

Is it because consumers believe that the batteries themselves leak, so the design is not questioned?

Is it because consumers are tolerant of such problems underwater because they know that the hyperbaric environment is a tough one in which to work?

Is it because Orca heads off trouble by acknowledging the complaints and is quick to repair the device?

Whatever the reason, Orca has put a great deal of energy and expense into addressing the leakage problems. And Nordstrom says they must. "We are in the business for the long run", he told us.

A Florida diver seems to speak for most Dipper owners who have been flooded out. "I trust the research and the tables it is based on. I am certain Orca will be able to correct the problems in time."

The Battery Door Again

Aside from the leakage problem, the comments issued by our readers are more minor annoyances than problems. The battery door, which serves as the on/off switch, is often difficult to manipulate. One reader said that "the O-ring on the on/off switch gets hard to move after one or two dives post siliconing, requiring teeth to turn". Another said, "I did not turn the 'on' button all the way and it slipped to off in the middle of a dive". And a third said, "The battery compartment flooded after I had pre-dive difficulty in manipulating the on/off switch on the second dive on a three-week trip to New Guinea. Good thing I carry backup gauges".

A number of other minor irritants were mentioned. "It fell out of the retaining holster in sixty feet of water". "Under normal use the display face cracked; it was not covered by warranty, although it was within the warranty period." "Automatically goes into 'battery save' mode within one hour after power-on if not in water. Did not realise this the first time and thought computer had not functioned" are some of the comments. And a few users complained about the general unavailability of batteries; they are specially designed for the Dipper and are available only from Orca or from dive stores.

There are only one or two reports of apparent algorithm malfunction, and those might be attributable to the flooding problems. Of course no computer is a guarantee against the bends, and sure enough, five readers reported incidents using the Dipper. A diver from Irmo, South Carolina, says: "The first time I used the Skinny Dipper I was wreck diving. Both dives were with the limits set by the Skinny Dipper. The first dive was within the Navy tables, the second dive was slightly over. I did a five minute safety stop. I got bent the next day". A Delaware diver says "I had a skin bends after doing a second decompression bounce dive following the first dive, back to back, no surface interval". A third bent diver says, "my fault, I wanted to take the computer to its limit".

Buy It Again?

Nineteen percent of the Dipper users do not know or would definitely not buy the Dipper again. That is the highest dissatisfaction rate among all the computers we surveyed, but it is a direct reflection of the leakage problem.

Divers who have not had problems dote on their Dippers. They like the size, they like the price, and they trust Orca.

A Californian diver says "I use it like Jerry Falwell uses the bible! I trust it to tell me the truth. I am a Skinny Dipper Fundamentalist!"

Buying a New Dipper

There may be a few leakers left on the shelves of dive stores. Before you take a Dipper home, check for two things to guarantee that it is a solid model. According to Nordstrom the serial number should be greater than 13,800 and it should have a black door.

The Next Generation

This summer the next Orca computer, the Delphi, is expected to hit the market. Essentially a Skinny Dipper that attaches to the high pressure hose and can read air pressure, its introduction may mean that in the future the Skinny Dipper will be used mainly as a backup computer. Or even, as one reader said, "I carry the Skinny Dipper to lend to others when I want someone to dive with me beyond the Navy Tables".

While most new computers on the market are powered by long-life (2-5 years) batteries that can only be replaced by the manufacturer, the Delphi will be powered by over-the-counter nine volt lithium batteries. We asked Nordstrom whether it was not risky business for Orca to produce a third computer that allows the diver to change batteries, given the leaky history of both the Edge and the Skinny Dipper. He told us that the Skinny Dipper design was based on responses of 15,000 surveys sent to divers, dealers, Edge users and their warranty base. The responses indicated that consumers want a computer with batteries they themselves can replace.

As long as the Delphi remains dry, it will probably be a winner. Orca has developed a loyal band of followers and the reputation of being strong on computer technology and customer service.

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THE SUUNTO SME-ML DIVE COMPUTER

A solid contender, if you remember to turn it on

In our last two issues, we provided extensive reports on the Edge and the Skinny Dipper, based upon responses to our questionnaires contained in a past issue of *Undercurrent*. In this issue we cover the Suunto SME-ML, on which 84 readers reported.

Manufactured in Finland, the Suunto produces extended bottom times similar to the Edge and Skinny Dipper. Weighing only four ounces, it is a much smaller device, its face is about the size of silver dollar, and is easily worn on the wrist or in a console. Suunto has used the limited space well; the device is only slightly less readable than the large faces of the Skinny Dipper and the Edge. It does most everything the Edge does, including providing the required decompression stop time (which the Dipper does not). It lacks a temperature readout.

The Suunto users reported general satisfaction with the computer. Only 11 percent said they either would not buy or were uncertain about buying a Suunto again.

On the other hand, 17 percent experienced a malfunction during a dive. To Suunto owners, two major problems stand out: the switch and the dive memory recall feature.

The Switch

Whereas the battery compartments of the Edge and the Skinny Dipper have proven to be their Achilles heel, Suunto has a different yet less difficult problem: the water-activated switch. Thirty-eight percent of the divers report troubles with it.

Activating the Suunto is a two-step process. First, it must be submerged in water; two contacts on the device are activated and within a few seconds the Startup display appears. Next, the unit must be removed from the water and kept in air for five to ten seconds. Activation should now be complete.

Simple enough, it seems, but not to everyone.

The first general complaint is that it does not always turn on properly. In the struggle to gear up and get into the water, many readers admitted that they simply forgot the two-step process. Says an Oklahoma City diver “My own failure to perform pre-dive check caused the computer to not switch on.”

If a diver has not checked the computer at the surface, it is necessary to return to the surface to activate it. A diver writes from Brandon, Florida, “If you enter the water without first turning it on and immediately descend, it will lock up in its self-testing mode, giving no readouts for the first dive and therefore the data for successive dives is inaccurate”. Another diver writes that “Some dive boats do not have water tanks aboard to start up computer. Once, I rolled in off boat, descended to bottom and realised I had not held computer out of water for initialisation. I had to surface with buddy to clear”. A woman diver says: “I just moisten the tips of my thumbs and forefinger and press the two nodes; it lights right up”.

Another problem is reported by an Undercurrent reader from Helsinki, Finland. “The computer sometimes does not start due to dirt on contacts. Clean the contacts with your fingers.” Another reader, also of Helsinki, said, “Once it did not start, but I found out that there was some grease and dirt on the rubber contacts. I have to wash it with sweet water after every use”.

Ron Cole is the Suunto products manager at Seaquest, the company that distributes Suunto in the United States (Fitzwright is the Canadian distributor). Cole says the problem is exacerbated when divers touch the contacts after touching silicon grease or applying sun block lotion to themselves. The oil attracts dirt as well as repelling water, both of which tend to negate the function of the water-activated contact points.

Divers who carry their Suunto in the console have had some trouble activating it. A diver from Grand Prairie, Texas, reports “Salt deposits build up in the console and cause malfunction, but instructions and factory memo warn against this neglect. Still a hassle to keep clean”. One diver reported that she blew air in the openings to clean it out. A Saratoga, California, diver says he has “difficulty getting computer to turn on without popping it out of the console”.

“The unit is fickle and sometimes hard to start when used in the console and not immediately rinsed on the previous dive”, writes a reader from Seattle. “Starting it more than an hour before a dive has caused me to forget to check it at the start of the dive. Invariably I will see the startup display at about 15 feet and have to return to the surface to get the computer into the dive mode. Usually this requires squirting air from my drysuit inflator onto the contacts to break the electrical connection and allow the computer to enter the dive mode. This is an extreme inconvenience, but it is only present in the console version and only occurs when I forget to recheck the computer before entering the water.”

Last June, Suunto added extenders to the console; they touched the contact points of the computer so it did not have to be removed to get it started. But the extenders caused their own problems: a film would quickly form around the metal pieces, keeping them wet and not responsive to the air. At the year’s end, Suunto modified the computer’s console boot. It now has square holes and rubber coating on the contact points and sells for $15. The extenders are no longer available.

The Suunto switch has created another unique problem for some divers. "When it hits air, even for an instant", a diver writes from Boca Raton, Florida, "it will assume you have jumped to the surface. It happened once when I raised my wrist into an air pocket in a wreck, and I believe it happened another time when it was hit by air from my regulator. Neither of these incidents caused a problem, but was not on a deep decompression dive at the time".

There was another complaint from a diver who, when he swam to dive sites, took his wrist in and out of the water. Another diver who surfaced in the middle of a dive to check his location reported that his computer began to register a new dive. An Indianapolis diver reports that his Suunto "activated itself to a depth of 20 feet and 0 minutes when it was hit with prop wash. It acted confused for a few minutes. Then began scrolling at a reduced bottom time. Another time, during a rinse-off it went into the memory recall mode!"

Cole acknowledged that the Suunto switch will activate in these situations. Wearing it on a console, which stays below the surface even when a diver's arms are in the air, mitigates the problem.

A doctor from San Diego, says that his Suunto recorded "phantom dives", which occurred by "pushing on the metal contacts and wiping out the recorded surface interval". The Boca Raton diver reports that his device is "Overly sensitive to momentary ascents to less than 5 feet and it will assume you are on a new dive (applies only to memory review feature, not to calculation of dive times)". A\diver from Belmont, California, says it is "not sensitive enough to 10-foot level, causing 'scrolling' function to record more dives than actual. These extra dives being all three minutes at minimum depth".

Cole responds that the Suunto measures depth in three-minute intervals and activates the depth measurement at about four feet. "Thus", he says, "if a diver goes to sixty feet for twenty minutes, surfaces to check his position, descends to twenty feet, swims to the boat, surfaces to wait for people to clear the ladder, and then is washed or dipped by a swell, the unit will indicate several surfacing periods, but will have only one dive on the computers. If someone is not aware of this, it will appear that several dives have been made."

Dive Profile Memory

A unique Suunto feature is its memory: it can recall any number of repetitive dives conducted during the previous ten hours. Unique, indeed, but difficult to master, as several of our readers report.

"The computer is supposed to scroll through previous dives", writes a reader but "the procedure is confusing and even if I follow the instructions, the computer does not perform properly". Another says the computer is "difficult to interrogate. It usually takes several tries to make the Suunto give the profile information".

Some of the memory recall problem may be related to wet computers. A Seattle diver says: "Once in a while I cannot retrieve information as soon as I want, waiting a short time (while it dries?) seems to solve the problem". A\doctor from San Diego says he has "problems getting it to cycle to recall dives, especially when wet".

Later this year, Suunto will simplify the procedure for recalling the memory; hopefully, the users of the newer models will have fewer problems interrogating the computer. In addition, the revision will scroll from the last dive backwards; the current model first recalls the initial dive, then runs to the current dive.

Reading the Face

The data on the face is reasonably large and only a couple of divers complained about the readability.

"You have to be aware of where a flashing display such as 'slow' is and means", says a diver from Ballston Spa, New York, "because it is difficult to read". From Newark, California, comes the comment "Bar graph display for maximum depth is difficult to use accurately for deeper depths; at night it is not easy to read with an underwater light". Of course, since the face is not backlit, reading it at night is difficult. A Culver City, California diver says "I use a rubber band to strap a cylume stick to my console".

The Battery

A diver from Helsinki reports having to change batteries "every 100-200 dives". Suunto tests of the battery in cold Canadian water found the battery would last about 1,000 hours or 100 dives. In the Caribbean, a few Suuntos got 3,000 hours or 300 dives out of one battery. They now advertise a minimum of 1,000 hours or 100 dives, Cole told *Undercurrent.*

Additional Comments

Several random comments are worth considering.

A diver from Algonquin, Illinois says his Suunto "actually malfunctioned after a dive and registered a maximum depth of 120 feet when I dove to 80-something feet (Navy table would require me to round up to 90 feet). I prayed! Since the computer made a 'conservative' error, I thought if anything it would give me a shorter next dive. I watched it very carefully". When we broached this comment to Cole, he said, "If I had been there I would have told him to send the unit back. There is something wrong with it".

A reader from Indianapolis says "it does not always shut off even when dry for 12 hours between dives. Once it was scrolling for 14+ hours". Cole explains that the Suunto uses tissue times as long as 640 minutes, so if a tissue group is fully saturated it may take as long as 48 hours to clear. "There is no comparison between the 12-hour Navy and the 48-hour Suunto tables."

One diver reported that his Suunto simply failed: "Prior to total failure, it gave erroneous readings". Two other readers reported failure and returned it to Suunto for replacement.

Conclusion

All things considered, complaints about the Suunto are generally minor. Overall, nearly 90 percent of the Suunto users would buy Suunto again. The reasons can best be articulated by the users themselves:

"I like the features, the size, the quality. I have had no problems with it, unlike other friends have had with some other manufacturers."

"I tried several others before I bought the Suunto and I like it best. While I very rarely make decompression dives, I like having the option to do so with my computer. Many other makes do not have this capability."

"I cannot find any other unit so simple, yet with so much information in such a small package."

"I feel comfortable with its information and procedures, within reason, of course."

"I like the long battery life and not having to change the batteries during trips."

Addendum

The Suunto SME-ML wrist model retails for $US 560. For $US 645, it comes with a pressure gauge mounted in a console. For $US 685, the console includes a compass. Later this year the computer will be modified to provide the maximum depth of the previous dive while on the surface and the memory recall will be modified.

Suunto is researching a new model, but, Cole says, it is unlikely that it will be introduced within the next two years.

Suunto/Seaquest, 2151 Las Palmas Drive, Carlsbad, California 92009, U.S.A. Telephone (619) 438 1101. In Canada, the Suunto is available through Fitzwright.

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THE LOWDOWN ON DIVE COMPUTERS AND ALL IN ONE VOLUME

There are but a handful of diving computers on the market, yet the seemingly infinite array of variables between the models makes it difficult if not impossible for the typical sport diver to make careful comparisons. Surely, most computers have different tables. Some permit substantially more bottom time than others. Some are designed for decompression diving and others are not. Additionally, there are varieties of depth limitations, ascent indicators, temperature readouts, warnings about flying before diving, and variations in weight and size, battery life, and warranty.

Thanks to NAUI Instructors Ken Loyst, who publishes *Discover Diving Magazine*, and Michael Steidley, a *Discover Diving* editor, the comparison is now easy. Their new book, *Diving with Computers*, uses a dozen charts with scores of variables to give a side-by-side comparison of nine computers and their tables.

For people interested in the bottom time each computer provides, the authors have conducted actual dives and recorded the readouts. The results are provided, as well as the author's analysis of which computers perform more conservatively than the others.

Charts also compare the display features prior, during, and after a dive, the depth limitations, the battery lives, and other data. Each chart is accompanied by description and analysis.

A chapter on guidelines for using the computers is especially useful. As an example of the kind of savvy information provided, the authors offer a procedure for computer failure:

"If the computer fails during the course of the dive, a diver should ascend directly to the surface being sure not to exceed the manufacturer's maximum recommended rate of ascent. A short safety stop at ten feet adds a margin of safety. If the computer fails during a surface interval, there are two alternatives. A single repetitive dive may be made using the adjusted no decompression limits from the computer if they were recorded following the previous dive and prior to the failure. Alternatively, repetitive dives may be made to depths less than 27 feet."

The authors also note three types of diving conditions presently identified as *not* fitting the mathematical models of computers:

Reverse profile dives. Dives where the diver spends the majority of a dive in shallow depth and then descends to the maximum depth shortly before surfacing.

Consecutive deep dives. Dives where the diver makes a series of multiple dives, all of which exceed the stated no decompression limits.

Repetitive decompression dives. Dives where the diver makes a series of multiple dives, all of which exceed the stated no-decompression limits.

Any divers contemplating buying a computer will be well served by studying this 105-page volume. And any divers who own computers ought to master the facts about their own devices.

Loyst and Steidley provide much clearer information than most manufacturers offer. At last, divers may be able to understand exactly what it is that their computers actually do and do not do.

Diving with Dive Computers is available, postage paid, for $ US 11.45 from Watersport Publishing, POB 83727, San Diego, CA 92138.

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SERIOUS SKINNY DIPPING

To the Naturist Society, a Skinny Dipper is one of their 200 members who join regular tropical diving and snorkeling forays. You see, these folks charter boats and go diving sans suits and skins.

Last year they dived Belize on the liveaboard *Pegasus,* whose captain, Maria Cook, doffed her swimsuit a mile out of Belize City and did not retrieve it for the week at sea. They have gone for the good diving at the Prospect of Whitby clothes-optional resort on North Caicos, as well as at Bonaire, and Guadaloupe.

As Douglas Triggs, leader of the group writes: "We and the boat became part of the living sea, moving with the waves and surrendering to the wind. We lived our vacation with the delicious feeling of a life more on the edge, a welcome counterpoint to the normal humdrum of our daily existences".

If you want to be a buff diver, contact Triggs: Box 2455, Colorado Springs, CO 80901 (719/634-2836).

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THE BAD OLD DAYS

DIVER NAKAMURA

Ted Egan

When the luggers all sailed away
from Roebuck Bay on that fatal day
the diver on the B19 was Nakamura,
not yet 21, from the land of the rising sun.
His homeland was the Island of Okinawa.

Chorus

But it's goodbye now, farewell
say goodbye to Okinawa.
For today they'll bury you in West Australia.
You will never be as one
with the land of the rising sun.
Sayonara, sayonara, Nakamura.

In the deepest holes of the Lacepede shoals
to fulfill the pearling masters goals
went the diver of the B19, Nakamura.
His quest for the lustrous pearl
as strong as his love for the beautiful girl
he'd wed when he returned to Okinawa.

From the west came a tropical squall,
then the mercury began to fall.
40 fathoms deep was Nakamura.
"Set sail" no time to stage
for the storm began to rage
and they dragged to the surface
the boy from Okinawa.

The agony's in his eyes.
An old Malayman cries
for he knows the bends have got young Nakamura.
Helplessly they cursed
as the diver's lungs near burst
and he died on the deck, the boy from Okinawa.

To the diver's cemetery at Broome
bearing gifts, all deep in gloom
they walked with the body of the diver, Nakamura.
Headstones face the west.
A thousand divers lay at rest
and they're joined today by the boy from Okinawa!

This song by Ted Egan from his record "NEVER UNDERESTIMATE THE POWER OF A SONG" published by Larrikin Records, is reprinted by kind permission of Ted Egan and Larrikin Records.