South pacific underwater medicine society

Journal/*Newsletter*

C O N T E N T S

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EDITORIAL

There have been several Diving Medicine meetings in the Australasian region this year, a sign of the active interest being shown in such areas of Medicine. Unfortunately the common overseas practice of minimal or nil reporting of the contents of papers has been followed in most cases. It is natural for many interested persons, unable to attend such meetings, to wish to discover what was said. Such seekers after knowledge will in most instances find it impossible to shake their thirst for information through approaches to either the authors or the conveners. One is much more likely to hear up-to-date thoughts at meetings than to come across them in books, and even should The Proceedings later appear in print there is likely to be a considerable time lag. It is hoped that those involved will give thought at future meetings to preparing brief notes on such papers and discussions, with a willingness to make these available to anyone interested ... including Editors. The atmosphere of a good discussion loosens restraints on the sharing of information and many a highly interesting case history is made public. Inertia being one of the major forces in the Universe, there is little likelihood that such cases will be formally written up at a later time, one excuse commonly offered for keeping information secreted away. All too often one reads that "a useful discussion followed" or that there was "a presentation of cases". The cynic might say that what is needed is more case reports and less generalisation.

As a particular example of this one can instance the Truk Meeting Report, a very welcome one but one which notes the decision of those present that the use of octopus rigs be made mandatory. No adequate reasons are given for what must have been a decision based on experiences at Truk. But just what did occur? Were many people running out of air, why was this occurring, and what response had those involved made in these incidents? It is hoped that the proposed report by Dr John Parer will be available in a later issue but even now there should be more information to back a somewhat remarkable suggestion. Is there any evidence that the buddies of those running out of air themselves had air reserves adequate for two divers or is this the design for doubling the incident rate? Nobody who listens to diving doctors talk, or watches them dive, will regard them as expert interpreters of safe diving techniques in all instances. This may seem in retrospect, the equivalent of the mythical council that built a first aid post the foot of a cliff rather than erect a fence at the top.

This issue ranges widely over the earth and the animals therein. We are favoured with a hot-from-the-pen report from American NAUI on impressions from their Incident Reports, the paper by Commander Warner on the 1976 North Sea diving fatalities associated with the off shore rigs, and his department's circular concerning the helicopter transfer facilities for divers still under pressure. Should such an incident occur it is hoped that the problems encountered are rapidly circulated to other areas as the problems associated with deep diving are truly International now. Dr Ian Unsworth, realising that not everybody has had the opportunity (or invitation) to work at the RNPL has supplied what may be the first of a series of articles on keeping dry while underwater, while two sources have shown how one can get wet in the bowels of the earth. Dr Tony Slark has some highly pertinent remarks to offer divers for their better safety. We are specially pleased to have the article by Professor Harold Heatwole, an world authority on Sea Snakes. Here they are treated as creatures who have a very satisfactory solution to the problem life beneath the sea's surface and not as bearers of poison fangs. There are also a number of reports on past events and some Idle Talk. The Journal may be late by dates but there is much here that is worth waiting for.

The NAUI report has much that deserves deeper study and discussion, not least the finding that their (conscientious) instructors are encountering many incidents during training. One can presume to believe that the low level of reports of such incidents from other sources indicates a regrettably unacknowledged lower safety awareness among the generality of diving instructors. Perhaps they accept too readily the occurrence of out-of-air situations in their pupils, as one example. Readers may also note a passing reference to the occurrence of Air Embolism associated with even normal ascents. This matter is relevant to the do you/don't you argument concerning the practising of "Free Ascent", a matter it is hoped to start discussing in later issues. YOUR opinion will be welcomed. The advice given concerning the teaching of ascent procedure deserves wide dissemination and this Journal is pleased to have the opportunity to act in this matter.

The mention of the inadequacy of information supplied in some reports, leading to an inability to fully assess the medical aspects of incidents, is yet one more cry for divers to help improve their own future safety by sending full reports of incidents. Dr Hattori, who we have published, is one of the sources quoted in this report. Perhaps our SPUMS members will now send some of the information they have to The Editor for STICKYBEAK ...

Commander Warner's paper shows that Oil Rig conditions can be fatal to divers. But there are obviously great difficulties encountered in obtaining details of what has occurred even where the Coroner or Procurator Fiscal becomes involved. The task of persuading both divers and employers that the full truth will ultimately be less expensive in cash and lives will be a hard and long one. Getting the Legislature to allow flexibility in the application of The Law will be no whit easier. It is hoped to have further papers from Commander Warner, a prospect we welcome.

Dr Ian Unsworth is one of the few men in Australia who can leave his office desk, walk a few meters, dive to 200 feet and never get wet. He now tells of the times in the UK when he could do this to others under possibly less confined conditions than at The Prince Henry Hospital. He has cautiously given his results without offering any conclusions. There are two matters worth immediate comment, one being the unexpected fate of the attendants. They suffered a bends risk greater than that of the subjects. Possible factors for consideration were the fact that the latter exercised more while at depth but rested, and were warmer, during the ascent. The protective value of oxygen during the last 10 feet of ascent schedule was noted. One may remember that Toussaint Recco exercised at his decompression stops, so perhaps we are not correct in present views about the place of exercise and rest in dive profiles. The reduced response of the heart to the demands placed on it by exertion under hyperbaric conditions may be another physical limitation that will become more significant as other problems are bypassed. The use of Atropine, while beneficial in some ways, introduces new problems. Life wasn't meant to be easy ... for divers.

Fitness is always to be assessed in relation to the task to be undertaken. In view of the totally unusual diving conditions to be met in underground waterfilled passages it is salutary to have two reports on spelaeological diving. Few readers may have been aware of the significant differences in the composition of air dissolved in underground waters or the relevance of such a matter to air-over-water suitability for breathing. And the lessening of rope strength in water after tying a knot could be important for safety planning. Dr Tony Slark has indicated several factors significant for safe diving; it is obvious that our interests should be in no way limited to the strictly medical aspects of diver performance.

The decision of the Minister of Defence, removing the Insurance requirements for civilians attending SUM courses, is welcomed. Both parties, civilian and naval, are likely to benefit from greater interchange of views and experiences. As civilian divers, both medical and lay, have received somewhat similar course facilities in the UK for a number of years without wrecking the Gosport or Alverstoke installations it is expected that the SUM will suffer no damage from this concession.

And now you are free to read the articles themselves!

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LETTER TO THE EDITOR From Dr MY Khan

Dear Sir,

I welcome the appearance of a correspondence column in the SPUMS Newsletter. Since reading Dr Knight's reply to my letter I have started to prepare a review on deep hypothermia as he requested.

However I have some other queries to raise. Dr Knight mentioned that Mr A was "unable to hold his water" and that he was unable to recollect "recent past history". Without any clinical examination or investigation the patient was diagnosed as a case of hypothermia. Dr Knight should have ruled out all differential diagnoses. Did Dr Knight exclude hgpoglycaemia, cerebral or coronary insufficiency, depressant drugs etc. ?

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(The above letter has been abridged to retain the essential points. Editor, Newsletter)

Reply by Dr John Knight

Dear Sir,

Dr Khan, perhaps quite rightly, takes me to task for not offering differential diagnoses. I admit the fault but medical writing should always be short and to the point. The point here is that the only diagnosis which encompassed the whole history was that of hypothernda. Mr A was normal to clinical examination which again supported the diagnosis of hypothermia. And one normally accepts the obvious diagnosis as being the right one.

I look forward to reading Dr Khan's paper.

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Protection for Historic Wrecks

The Federal Government has declared that the Historic Shipwrecks Act 1976 applies to waters adjacent to the coast. This has followed a ruling by the High Court concerning the validity of some legislation, a ruling that meant the West Australian legislation no longer provided protection. The director of the Western Australian Museum has been given powers to grant permits for exploration or recovery of shipwrecks and relics of historic importance off WA. These wrecks include the Dutch ships Batavia, Gilt Dragon, Zuydorp and Zeewyk.

THE CARDIOVASCULAR RESPONSE TO EXERCISE, WITH AND WITHOUT ATROPINE, IN AIR AT 8.5 ATMOSPHERES

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First published at RNPL, 1968

ABSTRACT

In 5 subjects exposed to a pressure equivalent of 250 feet on air, the peak exercise heart rate was reduced by 38% of that attained before pressure, while with atropine the reduction was 24%. It is suggested that the bradycardia of increased oxygen pressure synergises with that of increased nitrogen pressure, to produce this reduction. The relative increases in conduction time within the heart structure may be due to nitrogen absorption and the ventricular myocardium may be relatively more affected in conditions of atropinisation.

INTRODUCTION

Evidence has been accumulating that, at increased pressures of nitrogen and inert gases, the pulse rates of subjects in both resting and exercising conditions have been depressed.[1, 3, 4, 11] Some inert gases such as xenon, exert this effect even at atmospheric pressure[2]. The exact mechanism of this action has not been fully explained and the use of the electrocardiogram may be able to clarify the position. It is well established that oxygen breathed at one or more atmosphere's pressure will exert a depressant effect on heart rate,[5,6] that is vagal in origin.[7] It was the present intention to carry out an investigation of the pulse rates of resting and exercising subjects at 8.5 atmospheres absolute in Air and to obtund the effect of the increased partial pressure of oxygen, by the administration of Atropine. The results from five subjects provide the basis for this preliminary report.

METHOD

The subjects were healthy unconditioned civilian volunteers aged from 24-34. The experimental conditions were as near as possible identical for each of the runs made by the 5 subjects and any undue apprehension was overcome by the men diving as attendants for other subjects in the experiment.

The Electrocardiograms of the subjects were monitored from four MRC silver disc electrodes fixed to the limbs, giving 6 clinical leads by direct recording on a Sanborn multichannel UV recorder. Pulse rates were recorded from a Devices R-R wave instantaneous rate meter, and exercise pulses counted from the paper record of lead II.

A 500 cubic foot chamber was used for the runs, the depth being 250 feet gauge pressure and rate of descent 63 feet per minute. Time at pressure was 20 minutes and decompression time 1 hour 41 minutes, oxygen by mask was given for the last 10 foot stop of 25 minutes. Exercise consisted of a minutes' toe touching from the supine position at the rate of 40 per minute by metronome. This may be classified as severe exercise. This was selected in preference to a bicycle ergostat or gemini rubber cord exercises, as it also involved a positional change from supine to past the vertical of the trunk and enabled a quicker transition from exercising to complete relaxation.

The exercise sequence was rest for 15 minutes, exercise for one minute, followed by a further period of rest of 7 minutes before the start of compression. At 13 minutes from start of compression (ie. after 9 minutes at depth) a further minute's exercise was followed by complete rest till 13 minutes after reaching surface. Complete 6 lead tracings were taken, at rest before exercise. Immediately post exercise, and 2 minutes, 4 and 6 minutes post exercises. At all other times, slow speed lead II monitored the ECG. Pulse rates during rest were taken every minute, and every 15 seconds post exercise for 2 minutes.

The main task of the attendant who accompanied every subject was to ensure the subject was adequately covered with warm clothing before decompression and to fix the BIBS mask on the subject at the 10 foot stop. The attendant otherwise was at liberty to move and occupy himself as he wished. The significance of this will be discussed later.

The second section of the experiment required the subjects to repeat the dives after receiving 0.6 mg atropine sulphate intravenously immediately prior to the initial rest period.

RESULTS

The results indicate primarily pulse rate values before exercise, at the peak of exercise and at 2 minutes post exercise, on the surface, at 250 feet and on return to surface. Without atropine, the mean resting value pre dive was 56 beats per minute with an exercise peak of 197.

After 9 minutes at 250 feet, the mean resting pulse rate was 55 with an exercise peak of 121, showing a mean decrease of 38.5%. On returning to the surface, the mean resting rate was 51 beats per minute and on exercise, 183 beats/minute. Pulse rate values taken 2 minutes after cessation of exercise were 75 beats/minute pre dive, 59 beats/minute at 250 feet, and 62 beats/minute on return to surface.

After an intravenous dose of 0.6 mgs atropine prior to diving, the mean pulse values changed; resting on the surface was 69 beats/minute, exercise on the surface 182 beats/minute. At depth, the resting pulse was 67 with a mean exercise value of 137 beats/minute, and a mean percentage decrease of 25% over that on surface. The post dive resting level was 54 while this rose to 175 beats/minute with exercise. Two minute post exercise rates were 89 beats/ minute on the surface, 78 beats/minute at 250 feet and 81 beats/minute post dive. The figures are expanded more fully in Tables I and II.

The ECG recordings were examined and the PR intervals and QT computed and tabulated. The QT intervals were corrected for heart rate by the formula of

$$QT_C = \frac{QT}{\text{cycle length}}$$

The mean PR interval for all the subjects ranged from 0.152 seconds pre exercise on the surface, to 0.168 pre exercise on bottom. After exercising, the mean interval further increased in length to 0.171 seconds, while after return to surface and exercise, the mean fell to 0.148 seconds.

After administration of atropine the mean pre exercise surface PR figure was 0.150, shortening to 0.132 seconds after exercise. At depth the resting PR was 0.148 seconds but after exercise this shortened to 0.138 seconds. Post dive mean value for the PR interval were resting 0.162 and post exercise 0.149 seconds.

The mean corrected QT on the surface pre exercise was 0.368 seconds extending to 0.395 seconds after exercise. At depth the mean resting QT_C was 0.380 seconds and 0.388 after exercise. On return to surface, the mean QT_C resting and post exercise were 0.372 and 0.379 seconds respectively. With atropine the pre dive resting mean was

0.374, extending to 0.399 seconds after exercise. At 8.5 atmospheres, the resting mean was 0.393 increasing to 0.408 seconds post exercise. On return to surface, the mean corrected QT was 0.366 seconds resting and 0.376 seconds post exercise.

Apart from measurement of PR and QT intervals the ECG tracings were examined for any irregularity of rhythm. In no subject was any arrhythmia detected, except sinus arrhymia and this was noted to be abolished by atropine. Wave amplitude showed no change of any significance.

During the actual periods of compression lasting 4 minutes, the pulse rates of three subjects fell in a marked linear fashion from a mean pulse rate precisely at the start of compression, of 112 beats to a mean of 62 beats/minute on reaching depth 4 minutes later. It was subsequently noted that this compression-associated fall did not appear after atropine had been administered.

DISCUSSION

From several sources[1,2,3,11] it is becoming apparent that nitrogen at pressure and other inert gases at normal and raised pressures do have an inhibitory effect on the pulse rate and cause a resting bradycardia and decrease in exercise peak.

Shilling (1936) found in his subjects a drop in both pulse rate and blood pressure at 10 atmospheres of air. Pittinger (1953) while using xenon at atmospheric pressure as an anaesthetic agent for man reported a bradycardia and hypotension despite premedication with atropine. He also found that at 3% ATA, xenon gave quite marked bradycardia in monkeys. Unsworth, in published work, has found a definite depression of both the resting and exercising pulse of men in a 19/81% mixture of oxygen/argon at 4 ATA.

Helium has also been reported as having a pulse depressant effect by Hamilton (1966). He noted a slowing of the resting pulse and a depression of the exercise peak in oxy-helium at 650 feet. However, oxygen has been known to have this depressant effect, both at normal (Daly and Bondurant 1962) and increased pressure (Salzano 1966), causing a reduction of cardiac output of 10-12%, primarily associated with bradycardia rather than reduced stroke volume. This may be abolished by atropine as used by Daly and Bondurant or by vagotomy as shown by Whitehorn and Bean (1952). But this oxygen effect was largely overcome in the experiment of Hamilton by using a gas mixture containing 1.5% oxygen at pressure, equivalent to 35% at sea level. Pittinger, when using xenon as an anaesthetic agent at atmospheric pressure, employed an 80:20 mixture of xenon and oxygen.

In the presented series of dives to 8.5 ATA with air, oxygen partial pressure reached 1379.6 mm. Hg or (1.76 ATA) and this may be expected to exert an effect on the pulse rate both resting and at exercise. With a view to eliminating this, atropine, by intravenous injection, for speed of onset, was used. Exercise before and after pressure in both atropinised and non-atropinised subjects, showed the heart could respond to exercise by attaining high peak values but at depth, there was a mean exercise peak reduction in the non-atropinised subjects of 38.5%, with atropine the mean reduction of exercise peak was 24.96%. This reduction in exercise peak at depth, on initial observation, would appear unexpected. Many factors operate at chamber pressure that should increase the exercising heart rate above that attained on the surface. Such factors (Table III) include:

1. Increased air density resulting in
   a) increased resistance to body movement ;
   b) reduction of MVV by approximately 68%; leading to
   c) CO_2 retention with raised alveolar pCO_2 (Lamphier 1963, Jarrett 1966).

2. Increased thermal stress. (Maximum temperature at end of compression 45°C) especially with atropine.
3. Increased humidity.
4. Increased involuntary exertion caused by muscular inco-ordination attributable to nitrogen narcosis.

To produce a peak reduction, the agents that must be responsible are an increased partial pressure of nitrogen and an increased partial pressure of oxygen. That the reduction in peak is greater without atropine, than with atropine, is suggestive of the oxygen effect being synergistic with the depressant effect of the nitrogen. Both non-atropinised and atropinised exercise peaks returned to the pre-dive level after decompression in all but one case.

From analysis of the ECG, the PR interval and the QT interval (corrected for heart rate) appear to be affected at depth, being prolonged in the non-atropinised dives by a mean 12.58% and 5.56% respectively. However, the atropinised dives produced a mean reduction of PR interval at depth of 7.55% yet an increase in the QT_C of 9.1%. This difference between the non-atropinised and atropinised PR at depth is extremely difficult to explain but may be related to the increased atrial conduction associated with atropine. The increase in the lengthening of the QT_C with atropine is also difficult to explain but it may be due to the effect of an increased inert gas uptake at the greatest heart rate, both resting and exercising, during pressure, attributed to the use of atropine. The increased pulse rate results in a higher pulmonary uptake and similarly in a greater myocardial uptake particularly by the larger ventricular tissue mass. It would seem that impulse transmission between individual cardiac muscle fibres of the ventricular myocardium is more susceptible to interference from nitrogen under pressure than the more highly organised neuro-conduction system, between atria and ventricles. Continuing work on these lines using other inert gases is being conducted.

The observed fall in pulse rates of three subjects from a mean peak immediately on compression of 112 beats/minute to a mean level on reaching bottom of 62 beats/minute, is, I believe, the retention in the subjects of some element of the mammalian diving reflex, which in these cases would appear to act in the absence of water contact with the face, but in the presence of increasing air pressure. That it is a vagal reflex is well-demonstrated by its abolition with atropine. No complications or undue side effects were noted with the use of atropine. All subjects reported dry mouth and absence of sweating, and all were seen to have moderately dilated pupils. Two noted that the exercise plus the lack of sweating in the high temperature of the chamber (average temperature at time of exercise 35°C) resulted in their feeling pyrexic but body temperatures were not taken in this series. Exercise at depth produced a pronounced peri-oral pallor in 3 of the 5 subjects but no abnormal feelings were reported. On questioning at surface, the divers stated that with atropine, they felt ‘more alert’, ‘less sleepy’ and ‘more energetic’, an effect that may be of interest for further study.

An incidental finding to emerge from the experimental series was the apparently greater ‘bends’ risk of the attendant as opposed to the subject. Complete relaxation with slowing of circulation during decompression, and vigorous exercise after decompression have been looked upon as providing rather poor conditions for safe bubble-free decompression[10,12] particularly in association with maximal gas uptake just prior to leaving depth. In 6 preliminary dives, oxygen was not used on the last 10 foot stop and from 7 attendants, there occurred one bend and 4 ‘niggles’ but no problems of any kind from the subjects. It is suggestive that exercise at depth prior to decompression, by virtue of increased vasodilatation and blood flow most active during the first few decompression stops, has a protective function. The subjects also, were always made warm and comfortable before decompression, the temperature during which could fall to 3°C at the first stop. The attendant sometimes neglected their own comfort initially and may have become chilled by the rapid fall in temperature, vasoconstriction prejudicing their chances of a symptoms free decompression.

This effect of pulse reduction at pressure represents the influence of only a short exposure, in this case 13 minutes. Whether in a much longer exposure the heart and cardiovascular mechanisms will compensate for this inhibitory effect is not at present known, but obviously must be investigated, particularly in relation to long term saturation diving that has the express intention of enabling hard work to be performed for long periods at depth.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues and subjects for their valuable assistance and co-operation.

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TABLE I

RESTING AND EXERCISE PEAK PULSE RATES ON SURFACE AND 250 FEET

SUBJECT	Surface		250 feet - air		% Decrease from Surface	Surface	
	Resting	Exercise	Resting	Exercise		Resting	Exercise
JB	50	180	57	100	444	54	110
GC	61	216	53	114	47.2	51	204
TS	54	186	51	114	38.7	47	204
JT	40	210	49	156	25.7	43	204
IU	75	192	65	120	37.5	62	192
MEAN	56	196.8	55	120.8	38.5	51.4	182.8
S.D.	±11.7	13.9	5.7	18.8	7.5	6.5	19.9

ATROPINE

Subject	Surface		250 feet - air		% Decrease from Surface	Surface	
	Resting	Exercise	Resting	Exercise		Resting	Exercise
JB	75	180	75	138	23.3	51	162
GC	68	180	69	138	23.3	58	168
TS	65	180	68	134	25.6	56	162
JT	44	168	53	129	23.2	45	168
IU	95	204	72	144	29.4	61	214
MEAN	69.4	182.4	67.4	136.6	24.96	54.2	174.8
S.D.	±16.5	11.8	7.6	4.9	2.29	5.6	19.8

TABLE 11

EFFECTS OF EXERCISE AT 250 FEET

ON COMPONENTS OF THE E.C.G.

	SURFACE		250 FT - AIR		SURFACE	
	PRE-EXERCISE	POST-EXERCISE	PRE-EXERCISE	POST-EXERCISE	PRE-EXERCISE	POST-EXERCISE
PULSE RATE bts/min	56± 11.7	75.1 ± 11.9	55 ± 5.7	58.9 ± 4.9	51.4 ± 6.5	62.1 ± 8.9
P-R Interval (Secs)	0.152±0.003	0.156 ±0.009	0.168±0.009	0.171±0.009	0.168±0.009	0.148±0.009
Q-T (Corrected) "	0.368±0.016	0.395±0.019	0.380±0.022	0.388±0.022	0.372±0.014	0.379±0.018

	SURFACE		250 FT - AIR		SURFACE	
ATROPINE	PRE-EXERCISE	POST EXERCISE	PRE-EXERCISE	POST-EXERCISE	PRE-EXERCISE	POST-EXERCISE
PULSE RATE bts/min	69.4±16.5	89±13.2	67.4±7.6	78±6.2	54.2±5.6	81.8±5.3
P-R Interval (Secs)	0.15±0.008	0.132±0.009	0.148±0.015	0.138±0.013	0.162±0.011	0.149±0.013
Q-T(Corrected)Secs)	0.374±0.016	0.399±0.025	0.393±0.012	0.408±0.017	0.366±0.022	0.376±0.015

± Standard Deviation.

TABLE III

FACTORS AFFECTING PULSE RATE AT INCREASED AIR PRESSURE

1.	Air Density	a. increased effort of movement (inc. respiratory) b. decreased MVV - increased alveolar pCO_2
2.	Temperature	Ambient ($\propto$ rate of compression) body temperature
3.	Acoustic stress	($\propto$ rate of compression, chamber silencing) up to 130 lbs.
4.	Exercise	CO_2 production, catecholamines, temperature
5.	Psychological	Apprehension (central, catecholamines)
6.	Drugs	agolytics, tranquillisers, etc
7.	Increased gas partial pressure	Nitrogen and oxygen
8.	Nervous	Vagal 'diving mammals' reflex

FIGURE 1

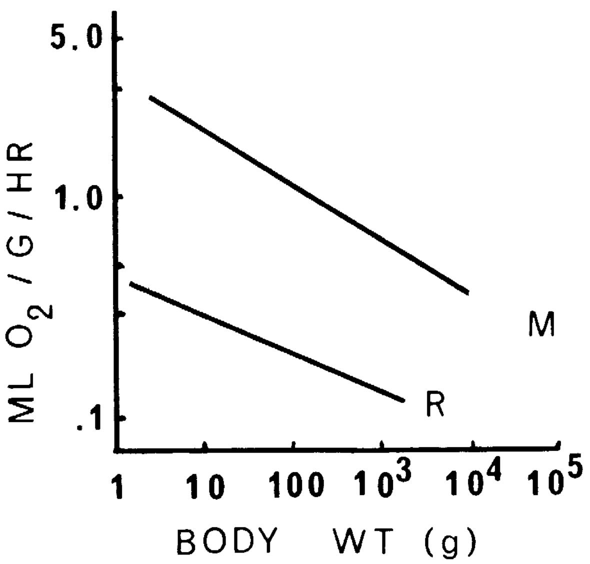
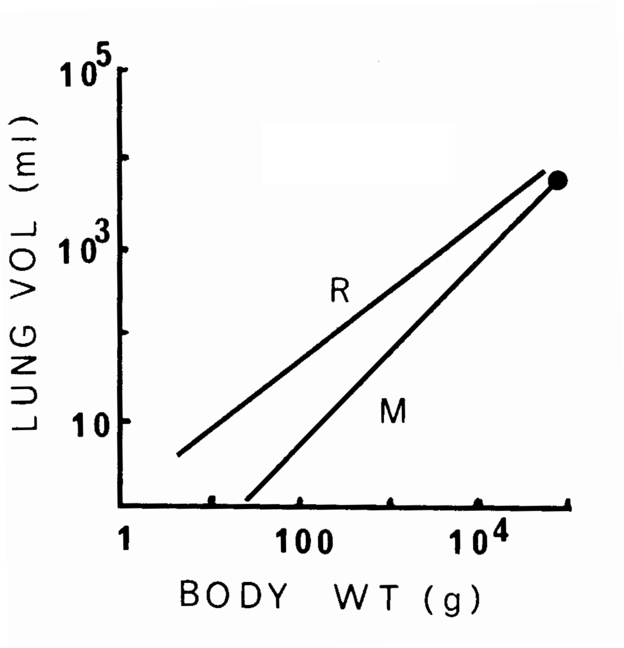


FIGURE 2



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NOTES TO CORRESPONDENTS AND AUTHORS

Please type all correspondence and be certain to give your name and address even though they may not be for publication. Authors are requested to be considerate of the limited facilities for the redrawing of tables, graphs or illustrations and should provide same in a presentation suitable for photo-reproduction direct. Books, journals, notices of Symposia, etc will be given consideration for notice in this journal.

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DIVING ACCIDENTS – WHY?

A REVIEW OF NAUI DIVING INCIDENTS REPORTS

John Hardy

Over 100 people lose their lives each year in scuba diving accidents.

URI has done excellent work but has not been able to review causative factors. Over 700 accident reports on file at NAUI Headquarters were reviewed taking a close look at possible causes. Training accidents were reviewed separately with special tabulations done on particular problems. Eight significant areas of causative factors were identified. Commentary with recommendations are provided on each area with particular emphasis on training modifications.

Two divers are moving slowly and uneasily through the water. The water is cold, visibility is limited and the divers are now deeper than they expected to be. Each is getting tired and cold. The first dive of the new year finds them more than usually nervous.

A late party, little sleep, much alcohol, even a couple of joints and very little food all contribute to a sense of unease, nervousness, even apprehension. The heavy use of tobacco coupled with little consistent exercise and no recent medical exam finds the divers not very fit.

Diving equipment has always been such a nuisance to them that neither of their tanks or regulators have ever been serviced since purchased. They just do not dive enough to get into all that fancy buoyancy control equipment or all those gauges.

The first diver, Joe, begins to have difficulty breathing, but thinks it is just his lack of fitness. He should not be low on air yet. He is sure his air always lasted much longer than this - last year. Besides it would be embarrassing to run out of air before his buddy, Hal, did.

Joe sees something of interest and moves in for a closer look. Sure enough, it is a partly buried anchor with the line still tangled in the weeds. He pulls and tugs, breathing harder all the time. Suddenly, there is no more air. He looks around, but his buddy has gone. He tries to move higher to see better, but something is holding him down...weeds...line...something.

Meanwhile, Hal has missed Joe and is looking around in a rather random manner, swimming hard to and fro. He sees Joe and moves over to him. Now Hal realizes that Joe is not breathing - fear grips him.

He thinks, "What was it we learned in the diving course?" He has had no refresher. No reinforcement.

"Ah, get Joe to the surface, but he is tangled". "No knife".

His air is low, it has already become hard to breathe.

"Try to pull him clear. Can I do it? No air at all! Go for the surface, now alone. Got to get out of here. Just cannot seem to get up, too heavy, swim harder, no air left. Got to hold breath to make the surface!"

Joe's body lies alone entangled in deep water.

Hal's body settles to the bottom in even deeper water, also alone.

... No two divers would ever make this many mistakes? Not so. This double tragedy is from actual occurrences in the recent review of the causes of over 700 diving accidents. The chain of events is frightening: cold, poor visibility, deep water, fatigue, stress, poor fitness, poorly equipped divers, ego, not staying together, poor skill levels. The result - two divers lost.

Two more tragedies that might have been prevented, thus two more reasons why legal actions, insurance and legislation will continue to be major problems for the sport of scuba diving.

In an effort to identify the causes of diving, accidents and suggest reasonable solutions, the National Association of Underwater Instructors (NAUI) conducted a complete review of all accident reports on file at NAUI Headquarters. The purpose of this work was to deal with causes of accidents, and more particularly, the role of training as a causative factor. The University of Rhode Island (URI) Reports deal with the statistics of location, day month, sex, age, autopsies and so forth. Thus, the URI Reports provide vital background information which compliments this study for a more complete understanding of diving accidents.

Results

Table I was developed by reviewing all available diving accident reports and counting each causative factor apparently contributing to the accident. The eight major categories are listed with individual sub-categories listed by frequency. These results may be biased due to geographic distribution or incompleteness of some reports (see Appendix A). The importance is not the exact percentage of a particular cause, but that these are now identified as primary causes of diving accidents.

Table II provides the same information as Table I when looking only at accidents that occurred during training. Since this is a much smaller statistical sample, a change of just one to five possible causes could completely change the order of the eight causative areas. Again, of primary importance is the identification of these listed causes as the ones most often contributing to diver training accidents.

TABLE I
GENERAL ACCIDENTS CAUSATIVE FACTORS CONTRIBUTING TO ACCIDENTS

	Causes	**Percent**
MEDICAL AND PSYCHOLOGICAL FACTORS:		
Decompression sickness, fatigue, drugs, heart trouble, stress, medical problems, cold, cramps, poor fitness, bad air	159	20
DANGEROUS ENVIRONMENTAL CONDITIONS:		
Surf, caves, deep, currents, visibility, ice, obstacles	150	19
BUDDY SYSTEM FAILURE:		
Loss of contact, diving alone	113	14
EQUIPMENT DIFFICULTIES:		
Misuse, lack of knowledge, trouble with regulator, lack of needed equipment, unable to use	102	13
RUNNING “OUT-OF-AIR”:		
“No-Air”, reserve misuse, air not on	92	11
ASCENT DIFFICULTIES:		
Buoyant, emergency swimming, buddy breathing, normal	78	10
ENTANGLEMENT:		
Kelp, weeds, lines nets, equipment	52	7
BUOYANCY CONTROL PROBLEMS:		
Overweighting, not wearing or using BC, BC not functioning	51	6
TOTALS:	797	100

TABLE II
ACCIDENTS DURING TRAINING CAUSATIVE FACTORS
CONTRIBUTING TO ACCIDENTS

	Causes	Percent
MEDICAL AND PSYCHOLOGICAL FACTORS:		
Stress, heart trouble, fatigue, drugs, medical problems	40	34
ASCENT DIFFICULTIES:		
Buoyant, emergency swimming, buddy breathing, normal	24	20
DANGEROUS ENVIRONMENTAL CONDITIONS:		
Deep, surf, visibility, obstacles, ice	16	14
BUDDY SYSTEM FAILURE:		
Loss of contact, diving alone	12	10
RUNNING "OUT-OF-AIR":		
"No-air"	10	9
EQUIPMENT DIFFICULTIES:		
Lack of knowledge, unable to use, misuse	8	7
BUOYANCY CONTROL PROBLEMS:		
Not wearing or using BC, overweighting, BC not functioning	4	3
ENTANGLEMENT:		
Kelp	4	3
TOTALS:	118	100

ANALYSIS AND COMMENTARY

Here is the data gathered through the reading of the accident reports plus the collective insights gained by the reviewers. These insights were items that did not "fit" the compiling of causes, but did indicate certain problems. The report is not intended to report precise statistical data, but to report the possible causes of diving accidents. Opinions and recommendations by the author are labelled as such.

Medical and Psychological Factors

General Accidents - 20%   Training Accidents - 34%

Decompression sickness was the most common non-fatal accident reported, most likely due to the need for chamber treatment. It should not be assumed from this that decompression sickness is the most common non-fatal accident. Several important insights were gained by a careful repeated review of just the decompression sickness cases:

* Most cases were not fatal.
* Most victims were experienced divers.
* In most cases, neither bottom nor surface time was recorded.
* Most cases involved over-extension of the tables but some cases were well within no-decompression limits.
* Age (over 35) and poor physical condition seemed to increase the likelihood.
* There appeared to be a number of cases which may have been decompression sickness, but were not reported as such.

An effort was made to review possible problems with decompression meters in decompression sickness cases. But there was not enough useable information to make any statements about the meter per se. It was indicated that if a meter was abused or not maintained, was used with no other instruments or was used without an understanding of the meter's limitations or of decompression in general, then there were difficulties.

Many problems were indicated by the reports but not actually recorded in the reports. These hard to find causes appeared to include heart attacks, air embolisms, fatigue, cold, stress or panic, poor fitness and the use of drugs, including alcohol.

A chain of events often appeared. The diver was cold and/or tired - stress level increased - the diver made a mistake - panicked, and death followed. The key link in this chain was the mistake which could have been anything from entering heavy surf to not maintaining the buoyancy control equipment properly and included all the other causes presented in this report.

Human error at three levels repeatedly appeared. In order of frequency they were:
1. The victim's error.
2. The buddy of the victim's error.
3. The instructor of the victim's error.

The use of drugs, including alcohol, increased significantly in the more recent reports. This may be a product of more complete reporting and/or a general increase in the use of drugs in the society at large. The use of drugs before diving appears to definitely predispose the diver to an accident.

Heart attacks were counted separately. Other medical problems were collectively reported as they did not occur nearly as often. Nearly all of these medical problems indicated the person should not have been diving, such as: respiratory impairment, regular medication, ear and sinus problems, epilepsy, recent serious operation, injury or illness.

Bad air was the least often found cause in this category. Again, the lack of complete reports, in this case, no analysis of the air after the accident, could cause this figure to be too low. Lacking further evidence it appears that the quality of air supplied to and used by sport divers is very high and bad air is an extremely minor problem.

Recommendations and Opinions

Divers need to stay fit. This includes regular medical exams, exercise, rest, good diet and avoiding harmful habits. In addition, divers should avoid getting tired, cold or excessively stressed during dives.

Student divers need to learn the medical and psychological reasons why to not dive. Instructors have an obligation to screen students as much as possible for the student's own health and safety. This screening should include: proper use of medical history forms, medical exams when needed, water skill and endurance evaluations, and a careful "tuning in" to student's physical and mental condition.

Conditions during diver training need to be controlled to avoid excessive stress, cold or fatigue. It is very likely that more students should be counselled during training, that diving is not in their best interest.

Dangerous Environmental Conditions

General Accidents - 19%   Training Accidents - 14%

Surf in California and caves in Florida are major problems. Ice and obstacles (trees, ledges, debris) are significant problems in fresh water, inland lakes. The deep diving problem was scattered in several areas with some dives being made to depths beyond any reasonable sport limit (200 feet or more). Most victims in cave diving and ice diving accidents were not properly trained or equipped.

Dangerous environmental conditions were often just one of several problems the diver was having, each of which the diver may have been able to handle, if it had not happened in surf, in a cave, under ice, or in deep water.

Recommendations and Opinions

Sport divers should be discouraged from cave and ice diving until they are properly equipped and have had special training.

Instructors need to take great care in not exposing student divers to conditions beyond their ability.

Student divers need to develop, during training, a strong sense of the importance of the decision to not dive. Therefore, it is suggested that instructors should cancel more open water dives right on location, explaining why they are doing so, directly to the students.

If the normal local diving conditions include surf, current or low visibility, then instructors have an obligation to teach students how to handle these conditions during all diving courses. This instruction needs to be conducted under close supervision and controlled conditions.

<u>Buddy System Failure</u>

General Accidents - 14%   Training Accidents - 10%

Diving alone does not kill divers, but being alone when something goes wrong does make it more difficult to escape safely. If a buddy were near at hand when the following problems occurred, then many fatal accidents might have been near misses: entanglement, out-of-air, bad air, heart attack, equipment difficulty, cramps, ruptured eardrum, fatigue, nitrogen narcosis, decompression sickness, head injury, regurgitation and air embolism.

Because of the inability of divers to stay together or due to diving alone, no one is then available when significant problems occur. No matter how experienced or well trained the diver, if some of these problems occurred in the water when alone, the chances of the diver surviving are greatly reduced.

Recommendations and Opinions

Instructors need to teach not only the tremendous importance and value of buddy diving, but also how to find and select a buddy, how to stay together, plus how to make buddy diving easy and enjoyable.

<u>Equipment Difficulties</u>

General Accidents - 13%   Training Accidents - 7%

Equipment difficulties tended to be interrelated with each other and with other categories of causes. Usually an equipment difficulty did not appear as a sole or primary cause of trouble. The vast majority of the problems with equipment were human errors concerning the use, care and selection of the equipment.

Dives can be made without certain items of equipment, but when these pieces of equipment are needed and not in use, this lack of equipment may then contribute to an accident. Missing items of equipment included: submersible pressure gauges, buoyancy control equipment, protective suits, snorkels, depth gauges, compasses, and watches.

Misuse of equipment was the most frequent equipment difficulty.

Specific problems included:

* Regulators attached incorrectly
* Back packs mounted improperly
* Quick releases not used on weight belts or scuba straps
* Weight belts not clear to be ditched
* Snorkels not worn on masks (in conditions of strong current, this may be an acceptable procedure but not under most conditions)
* Spearguns loaded out of the water
* Divers using BC's as lift bags
* BC or vest not maintained or checked
* BC not inflated for surface resting
* Air not turned on or not turned on all the way
* Cylinders not internally inspected
* Valves not serviced
* Using torn or ill-fitting wet suits
* Fin straps not properly buckled or secured
* Overweighting and/or over inflation of BC
* Improper positioning of the reserve valve
* No maintenance or home maintenance of the regulator (these two were the reasons behind most of the items listed as "trouble with regulator")

Recommendations and Opinions

Other equipment difficulties appeared to concern not knowing how to use the equipment, possible because of not being provided training during the original scuba course, forgetting previous training, using unfamiliar rented or borrowed equipment, or using equipment which was not available during training.

There are definitely some changes needed in diver training to provide more equipment skills, i.e. the selection, use and care of equipment. These equipment skills need emphasis without compromising other vital diving skills. Emphasis should be placed on the following:

* Selection of proper and complete quality equipment for the particular diving activity and environment.
* Proper preventative maintenance by the individual diver and regular professional service.
* Using new or unfamiliar equipment only under controlled conditions.
* More equipment handling during diving courses.
* More training on buoyancy control systems, both weights and inflatable devices.
* Limitations and need for training on new and advanced equipment.
* Not loaning equipment to untrained divers.

<u>Running "Out-Of-Air"</u>

General Accidents - 11%   Training Accidents - 9%

The quotation marks around "out-of-air" are important because most of these situations were actually low-on-air problems (100-500 psi).

Many divers had no submersible pressure gauge or reserve. Of those divers who did have them, many did not use them. Although the air not being turned on was an uncommon accident, it did lead to several unfortunate fatal accidents.

Reserve misuse or trouble with the reserve was one of the more surprising findings of the report. All of the experienced divers and instructors doing the review at first had assumed that this problem would be due to the reserve being in the wrong position (due to not being checked or accidentally bumped or pulled down). But, in 9 out of 11 fatal cases, the victim did not use the reserve when the air ran low, but panicked and went for the surface.

Table III presents the action taken by divers involved in "out-of-air" situations. The near equal distribution (one-third/one-third/one-third) is interesting, but the question remains, "What action was taken by divers who were completely successful?" The cases reported here reflect accidents or unsuccessful actions.

TABLE III
ACTION TAKEN WHEN "OUT OF AIR"

	Causes	**Percent**
Independent ascent to the surface	34	37
Buddy breathing ascent to surface	31	33
Unable to surface (panic, overweighted, entangled, cave, ice)	28	30
TOTALS:	93	100

Recommendations and Opinions

When divers are low on air, tired and cold, near the end of the dive, in deep water, they may increase their respiration rate. This is exactly the wrong behaviour under such conditions.

Training definitely needs to emphasise slow, deep, relaxed breathing; no "panting into the regulator"; avoiding deep diving; taking it easy; keeping 300-600 psi for the surface; use of both submersible pressure gauges and reserve warning mechanisms (audio or J-valve); turning air valves all the way on; double checking reserve, gauge and regulator function before entering the water; better buoyancy control; and ascent procedures.

Ascent Difficulties

General Accidents - 10%   Training Accidents - 20%

This was an extremely difficult category to list in order of frequency, due to the confusion of terms used for ascents. It was obvious that normal ascents caused the fewest problems and are the most often used ascents, butt a number of accidents did occur. Normal ascents and other ascents where everything was done "right" still led to air embolisms. Clear and direct evidence is not generally available in these reports, but medical problems, such as: respiratory impairment from heavy smoking, recent cold or infection, or previous lung diseases were indicated in these "correctly" done ascents, or it may by that ascent was not actually done correctly.

When making reference to air embolism, in this report, all related injuries: pneumothorax, emphysema, etc. are included. No attempt was made to sort the injuries or to make medical value judgements. It appears there may be more air embolism related injuries than reported, but these could not be counted.

While the octopus appears to have definite possibilities for improving diver safety, its use is also causing some problems. These problems appear to centre around: 1) where and how it is attached; 2) the procedures to be used when it is needed; 3) the actual first and second stage combination used.

Table IV provides additional detail on the apparent problems which caused buddy breathing to fail. There appears to be a problem when buddy breathing is aborted. This aspect needs more study.

TABLE IV
PROBLEMS DURING BUDDY BREATHING ASCENTS

	Causes	**Percent**
1. Aborted and changed to swimming ascent	20	43
2. Disorientation or panic	15	33
3. Struggle over regulator	4	9
4. Unable to clear regulator	4	9
5. Donor runs out of air	3	6
TOTALS:	46	100

Recommendations and Opinions

Buddy breathing has become an area of increasing concern. It is a difficult skill, to learn and maintain, and often appears to be unsuccessful. Since the frequency of successful buddy breathing ascents versus other forms of ascent is not known recommendations in this area are limited. But in order to give some indication of which ascents are being used, an informal survey of ascents made under emergency conditions by experienced divers was conducted. All possible types of ascents were mentioned as having been used successfully, but independent emergency swimming ascents were by far the most often given as the successful method used. Buoyant and octopus ascents were the next two most commonly mentioned successful ascents.

Using the insights gained from repeated detailed readings of these ascent accidents, the best available recommendations for <u>diver</u> ascent procedures are (in order of preference):

1. Make a normal ascent after stopping activity, breathing easily and getting control of the situation.
2. Make a shared air ascent, using the buddy diver’s extra regulator, if the buddy is so equipped and is closer than the surface, or if there is an obstruction to the surface (ice, cave, wreck, heavy kelp, etc.)
3. Make an emergency swimming ascent in a manner as near to a normal ascent as is possible: looking up, regulator in mouth, swimming a bit faster, exhaling more and inhaling less (lungs at near normal volume).
4. Make a buoyant ascent by ditching weights and/or inflating the buoyancy system; with regulator in mouth, looking up, and exhaling more rapidly.
5. Make a buddy breathing ascent only when the other options are not available.

In a comparison of ascent difficulties with general accidents and training accidents, ascents moved from sixth place to second place; from 10 percent of the causes. But also note that general diving accidents were involved 78 times while training accidents only 24 times. Ascents are definitely of serious concern during diver training, but the simplistic answer of not providing ascent training would simply move some accidents from training situations to general diving situations and most likely cost even more lives. The changing pressure during scuba diving is a unique and possibly risky aspect that does need more careful attention.

In order to more effectively and safely teach ascents, during <u>diver training</u> some recommendations are possible from reviewing these accident reports. Instructors should:

1. Provide lecture coverage on all forms of ascents used by sport divers.
2. Provide pool or shallow confined water training in normal, octopus, emergency swimming, buoyant, and buddy breathing ascents. Several of these procedures can be practiced horizontally.

3. Provide open water training in normal, octopus, emergency swimming ascents and buddy breathing in a stationary position.
4. Provide complete training in lecture, pool and open water on buoyancy control during ascents, ascents, at the surface, at the bottom and in midwater.
5. Make all open water emergency swimming ascents as similar to a normal ascent as possible, ie. regulator in the mouth, looking up, going slowly, but exhaling more and inhaling less, ie. keeping lung volume as near normal as possible.
6. Have divers look up as much as possible while making all ascents.
7. Make careful use of medical history forms with medical exams and chest x-rays when needed, plus take special care with any student who has recently had a cold, or is a heavy smoker.
8. Provide close supervision during all ascent training.

Instructors during open water ascent training should:

1. Not have students make any ascent that cannot be stopped or that is done at a high rate of speed, such as a buoyant ascent.
2. Not have students make “free ascents” or do a “blow and go”.
3. Not have students’ air turned off.
4. Not have students breathe off BC’s.
5. Not have students buddy breathe vertically.
6. Not have students take the regulator out of their mouth during ascents.
7. Not have students make anything but normal ascents from depths greater than 40 feet.
8. Not put students under undue pass/fail stress during ascents.

These are the best recommendations available after retreated review of the available accident reports. Far more research needs to be done on ascents. The problems and the solutions are not simple or obvious. All of these recommendations came from specific fatal cases where the lack or use of a particular procedure definitely appeared to contribute to the accident.

Entanglement

General Accidents - 7%   Training Accidents - 11%,

Entanglement has been viewed by some serious divers as a Hollywood movie or TV contrived situation that rarely occurs to divers. This is definitely not so! Entanglement contributes to at least seven percent of diving accidents, making it a problem needing serious attention. Kelp (mainly in California); weeds in lakes; lines (fishing, anchor, safety, etc.) in all waters; nets and equipment are all involved.

Recommendations and opinions

Buddy diving, use of a good knife, and underwater equipment handling during diver training are important in order to deal with entanglement. More controlled open water diving under the supervision of an instructor would increase diver skill and confidence, particularly the ability to think underwater and avoid entanglement or deal with it calmly.

Buoyancy Control Problems

General Accidents - 6%   Training Accidents - 3%

Often, buoyancy control was indicated as a contributing cause, but the reports were not clear enough for it to be identified as being significant. Only the clear cases were counted. Had accident reports been better, the buoyancy control problem might likely have been much higher in the list.

Overweighting, in particular, appeared to be a problem often not reported. Overweighting is also an increasing problem with newer systems, where the diver wears too much weight and then compensates with the buoyancy system.

Some divers did not use any inflatable devices to control buoyancy, others did not use adequate devices and still other divers did not maintain or check the devices so they would function when needed.

Fewer victims in these accidents had inflated their own flotation devices. No victim in any of the fatal reports successfully dropped their own weights, but most rescuers did ditch the victim's weights. Some weight belts or weight systems did not release when the victim or the rescuer attempted to ditch them.

Recommendations and Opinions

Much more training is needed during all diving courses on buoyancy control. Repeated use of conventional BC's and weight belts, along with at least an introduction to the newer or more advanced systems is needed.

Proper buoyancy control will make a distinct contribution to reducing accidents from other causative areas, particularly during ascents. Instructors should provide complete training in lecture, pool, and open water on buoyancy control during ascents, descents, at the surface, at the bottom and in mid-water.

Divers should weight themselves for neutral buoyancy, at the most common or shallowest depth. There is evidence that if a diver inflates the buoyancy control device or gets rid of the weights so surface floating is possible, this will often change a possible fatal accident into a near miss.

Location or Depth Accident Started

Table V provides information on the depth of the diver when the accident started. Some instructors have been saying, "most accidents start at the surface". In addition, URI has provided information on the depth of the body when recovered in fatal accidents, but no careful tabulation had yet been done on where the accidents started.

In the depth range underwater down to 60 feet, 43 percent of the accidents began. This range can be assumed to be the most common depth range for sport scuba diving. To be sure, most victims with or without rescuers went for the surface in an attempt to solve the problem and may have died on the surface and/or later been recovered from depth.

TABLE V
LOCATION OR DEPTH ACCIDENT STARTED

		Causes	**Percent**
Surface		115	26
0 - 60'		187	43
60 - 130'		96	22
Over 130'		38	9
	TOTALS:	436	100

Experience of the Victim

Table VI deals with the experience of the victim. The URI reports for 1970 through 1974 indicate 8 to 9 percent of the fatal scuba accidents occurred during formal training compared to 15 percent in Table VI. This supports the view that the records available to NAUI are biased in the area of training.

Many of the victims who were untrained were recorded in the older case reports, particularly those prior to 1972. This number appears to be decreasing. The number of accidents occurring when non-divers were being "trained" by friends who were divers was still sadly larger than expected.

Judging by this table, the first 12 dives or first year of diving are the most hazardous. It has been pointed out by many authorities in sport diving, that the majority of divers probably drop out during the first year. Thus, far fewer divers are left, who may also be better divers.

TABLE VI
EXPERIENCE OF THE DIVER/VICTIM

	Causes	**Percent**
Untrained	57	14
In training	60	15
Less than 1 year or 12 dives (certified)	145	36
One to three years or 12 to 48 dives (experienced)	79	20
More than 3 years or 48 dives (very experienced)	60	15
TOTALS	401	100

Training accidents tended to occur on the first open water scuba dive. Additionally, training accidents tended to be near misses when the instructor was immediately available.

CONCLUSIONS

Based on the wealth of information provided by these reports, several recommendations can be made for the modification of diver training courses. These recommendations are:

1. More controlled open water training under a variety of conditions, supervised by an instructor.
2. More careful medical and physical screening of student divers.
3. More emphasis on practical open water skills, particularly equipment handling, buddy diving, buoyancy control, dive planning and ascent procedures.
4. More emphasis on the prevention of fatigue, stress, getting cold, running out-of-air, emergency ascents, entanglement and decompression sickness.
5. More definite training in the environmental, medical, physical and psychological reasons why not to dive, when to abort dives or why to limit diving under certain conditions.
6. More emphasis on diving with complete, well maintained equipment of good quality.

Recommendations to already trained and certified divers include:

1. Know when not to dive; know when to abort the dive - never be embarrassed to do either.
2. Take an open water or advanced course.
3. Stay out of dangerous water conditions.
4. Get a regular medical exam and maintain physical fitness.
5. Buddy dive conscientiously with agreed upon procedures and a dive plan; know hand signals and each other's equipment; stay together.
6. Get complete quality equipment and maintain it well.
7. Know and use the equipment and procedures to avoid or handle running out-of-air, making emergency ascents, getting entangled and decompression.

8. Control buoyancy to make diving easier.
9. Get out of the water if cold, tired, hurt, out of air or not feeling well.

Additional research is definitely needed. A great deal more information could be gathered from an extensive study of near misses; taking a close look at what emergency procedures were used successfully. More accident reports are needed. All available information and reports should be sent to NAUI and URI. Also, far more and more complete autopsies are needed.

Specific aspects that need more study are:

* Decompression meter use.
* Non-treated decompression sickness.
* Medical problems related to air embolism.
* Problems due to drug use.
* Ascent procedures.
* Buoyancy control procedures.
* Emergency and rescue procedures.
* prevention of fatigue, cold and stress.

Information in the form of reproduceable safety handouts is provided with this report (see Appendix B). Much of this material was developed in conjunction with a review of this study.

Within the limitations stated in the basis and bias section (see Appendix A) of this report, this is the most extensive information available on the causes of diving accidents and the implications for both the practice and instruction of sport diving. The intention has been not to provide absolute statistical data, but rather to advance the current understanding of how sport divers get into trouble and by so doing, suggest how they can better enjoy a safe, comfortable open water scuba diving experience.

APPENDIX A

1. ACCIDENT REPORTS AND FORMS

   a) Accident Report forms - no charge
   b) US Underwater Fatality Statistics (URI) - $2.00 each
   c) Diving Accidents - Why? (NAUI) - 52.00 each.

Write: (For, a b or c)
NAUI Headquarters
PO Box 630
COLTON CA 92324

(For a or b)
URI Scuba Safety
PO Box 68
KINGSTON RI 02881

2. ACKNOWLEDGEMENTS AND BACKGROUND

Over 500 volunteer hours, in addition to NAUI Headquarters Staff time have gone into carefully reviewing and compiling this information.

Reviewers included:

Robin McFaddin, Ryan Taylor and Charlie Wheatley from Our World Underwater Scholarship.
Jon Hardy, Ken Kivett and Laurel Touchette, NAUI Instructors.
Mike and Rod Nachman, NAUI Divers.

3. BASIS AND BIAS

There was no attempt to find and review every case that occurred year by year in this report. URI reports provide that information. Table VII lists all available reports reviewed, by year.

TABLE VII
ACCIDENT CASE REPORTS REVIEWED

Year	**Fatal**	**Near Miss**
1965	12	—
1966	17	—
1967	19	—
1968	18	—
1969	20	—
1970	36	—
1971	45	—
1972	51	2
1973	82	6
1974	51	26
1975	56	51
1976	75	84
1977	12	18
Unknown	4	29
	498	216
TOTAL ALL ACCIDENTS:	**714**	

As this study was limited to cases on file with NAUI, there are several biases which should be explained. These biases should not significantly affect the usefulness of the report.

* As NAUI is an instructor association, with certain accident reporting requirements for insurance purposes, there is a greater proportion of training accidents than in the URI reports.

* Much better records are available from Hawaii due to the efforts of Roy Damron, NAUI Instructor and from California due to Dr Takashi Hattori of Monterey, the Los Angeles County Department of Parks and Recreation, and San Diego Lifeguards.

* Due to the number of NAUI instructors and their teaching activities in certain states, more and better reports are in NAUI's files from California, Hawaii, Washington, Texas, Florida and Massachusetts, and therefore, any environmental conditions or diving activities peculiar to these areas may be somewhat exaggerated in this report.

* Some of the reports were obviously incomplete and inaccurate.

* The near-miss reports tended to be more complete and filled out by instructors, particularly on accidents involving chamber treatment.

* The accident report reviewers did not make value judgements, but recorded apparently known facts or causes.

* In many case reports, certain facts were indicated, but due to lack of information, obvious inaccuracies or no autopsy being performed, these apparent facts could not be counted in this report. For example, decompression sickness, air embolism, heart attack, use of drugs, poor fitness, fatigue, cold or stress

may have been indicated but not explicitly reported. Information on the amount of weight used, use of reserve or pressure gauge, inflation of the flotation device and the type of ascent used were often omitted.

The total number of causes exceeds the total number of accidents as many accidents had multiple causative factors contributing to the accident. Also, due to incomplete reports, no cause could be determined in some of the accidents.

* When the review of these cases began, 16 categories were developed for possible contributing causes. After the review of several hundred cases, it became obvious that only eight useable categories existed.

* The reviewed reports included both general and training accidents of divers certified or in training by the several different diver certifying agencies.

PROBLEMS WITH THE MOSES SOLE

People who have read about the Moses sole (Pardachirus marmoratus) and the shark-repelling fluid it secretes wonder why, if this fluid is so effective it is not being used to protect divers and swimmers.

It has been found that though this toxin will repel sharks the effective use of the secretion will require the solution of several problems. The toxin itself is very unstable and some method of preserving it must be found. Then, because chemicals scattered around a diver disperse too fast to provide effective protection, the toxin would have to be incorporated into an ointment that a diver might apply to himself. It so, danger exists that the toxin may get into the bloodstream through the diver sustaining a cut. The toxin is both a neurotoxin and a homotoxin and will attack and destroy red blood cells. The ultimate solution to this problem may lie in the way the sole itself escapes such ill effects. This is still being investigated.

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ICEBERG TOWING IS A SOUTH SEA BUBBLE

The idea that Saudi Arabia and Adelaide could be supplied with fresh, though possibly centuries old, water seems to have been put back (as one might say) on ice. At a conference in Iowa in September, devoted to the theme of Iceberg Utilisation, Prince Mohammed el Faisat of Saudi Arabia supplied ice flown by helicopter from an Alaskan glacier to cheer the delegates. Apricot nectar was added to shavings from the two-tonne $7500 ice cube. And now Cicero, the company set up in France to tow a berg to Saudi Arabia, has gone bankrupt and a number of people are left out in the cold, cold wind of adversity. Apparently it was found that the ice might melt when removed from its natural environment. This financial misadventure is unlikely to cool the ardour of future Merchant Venturers, as such persons would have been called in days of yore. In fact the Oceanic Research Foundation has plans to take a berglet the short tow from the coast of Antarctica to Macquarie Island.
It is likely they intend something a little stronger than apricot nectar with their ice cube when they reach their destination. But this is hardly a new initiative, for last century a sailing ship towed an iceberg to Valpariso in Chile. Men were MEN in those days!

DIVING PAPER

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For the past 2 years I have tried to keep you up-to-date with the progress that the United Kingdom is making in the introduction of legislation covering the safety of offshore diving. You may remember that the United Kingdom introduced the Offshore Installations (Diving Operations) Regulations of 1974 on the 1st January 1975 and these were followed very quickly by the Merchant Shipping (Diving Operations) Regulations in March 1975. Last year in July we introduced the Submarine Pipelines (Diving Operations) Regulations 1976. These three sets of Regulations now cover all the diving to do with offshore oil and gas exploration and exploitation in the British sector of the European Continental Shelf. The reason for this piece-meal introduction was pure expediency. During this year it is our intention to replace these various pieces of legislation by a common diving safety regulation which will include not only the offshore industry but also diving in docks, harbours and inland waters.

Last year I gave you the broad details of the fatal diving accidents that had occurred in the whole of Northern Europe since 1971 in operations associated with the oil and gas industry. You may remember that the total for fatal accidents from 1971 until the end of 1975 was 25. I would dearly have liked to have come here this year and told you that that figure had not changed. Unfortunately in 1976 we had 9 fatal diving accidents offshore.

It is never pleasant to talk about accidents but I believe that the salient points and the lessons learned from accidents should be made public so that everybody concerned can do their best to avoid making the same mistake again.

In January 1976 a diver was lost whilst operating at a depth of 480 feet. His death was due to drowning and, without going into too much detail it would appear most likely that his main gas supply valve in the diving bell was accidentally shut. This is why we have banned the use of ball valves for such systems unless they can be secured positively open or shut. The diver concerned was carrying an emergency bale-out bottle but did not use it.

Again in January 1976, a diver was lost and another diver very seriously injured when a diving bell accidentally surfaced. Once again we learned a lesson from this accident. The diving operation was being conducted from a comparatively small vessel and to avoid the ship movement being imparted to the bell through the lifting cable, the bell weights were so arranged that they hung below the bell and could be lowered to the sea bed and the main lifting cable slackened off. However, during the diving task it was necessary to move the diving bell. During this operation the bell accidentally surfaced with the bottom door open. Subsequent investigation showed that some types of seabed conditions can create a tremendous suction on a weight or anchor or weight array far in excess of the actual weight of the ground tackle.

In May last year a diver was drowned whilst operating in 120 feet of water due to the fouling of his umbilical in a tide way.

Another diver died from pulmonary barotrauma after a dive to 120 feet. This was possibly due to a dormant weakness in his chest.

Another diver was lost through drowning whilst diving on air at a depth of 120 feet. We are having considerable difficulty in pinpointing the actual cause of this accident, but there are indications that suit inflation gas should not be taken from the breathing system.

In July of last year another diver was lost whilst operating from a barge in the North Sea and this was almost certainly due to his main gas supply becoming disconnected at his mask. The design of his particular equipment negated the value of his bale out bottle under these conditions. I cannot say more as a prosecution has been initiated.

In November two divers were lost in what can only be described as a surface interface accident. After returning to the surface both divers received injury through contact with the anchor bolster or cow-catcher of the installation and drowned.

On Christmas Eve another diver was lost on the surface and this is still being investigated.

We are still in the process of analysing the figures that we have to date, and of course this must be a continuous process. The figures suggest a broad breakdown of reasons something like:

human error	19
poor physical condition	3
inadequate training	6
equipment failure	9
lack of equipment	3
inadequate medical supervision	2
poor diving supervision	11
poor equipment maintenance	4
surface interface weather conditions	5
inadequate decompression schedules	nil

You will appreciate that quite often there are more than one or two reasons for an accident occurring.

In addition, as I told you last year, cold has certainly been a contributing factor in at least three and probably many more cases. Because of this, one of the first amendments to the diving regulations is going to require external body heating for dives deeper than 50 metres, and in addition, respiratory gas heating deeper than 15 metres.

As a result of investigations into the various accidents, near-miss reports and research programmes the Department of Energy issued 20 diving safety memoranda in 1976. They covered such things as advice on diving from small craft and vessels, advice on the diving bell weight systems, the use of high pressure oxygen in diving breathing systems, advice on medical emergencies, defects found on commercial breathing equipment, first aid medical emergency equipment that should be available, danger from suction on ballast weights or diving bells, the use of self-contained underwater breathing apparatus, advice from a jury during an inquest, advice on diving with suppressed cathodic protection on offshore installations, faults found in the gas supply systems, advice on the design of lifting harnesses for a bell diver, advice on the need to test pre-mixed gases etc.

The problem of bone necrosis is one that the industry has to face but I am pleased to say that all the indications at the moment are that this disease is not nearly as bad as we once thought it might be for the deep diving industry. In the United Kingdom, bone necrosis is accepted as one of the conditions arising under one of the prescribed industrial diseases for which the industrial injuries benefits of the Social Security Act can be paid.

These regulations apply to inshore diving only at the moment but will be expanded to cover the offshore industry.

When a person contracts necrosis it will have to be registered and apart from the industrial benefits that may be available it should also help to clear the air in cases of litigation. I believe that this is a very positive step in the right direction.

We are continuing to study the problems of evacuation of divers in saturation or long decompression. There are two philosophies that have to be considered; does one provide a seat in a lifeboat for everybody or does one accept the modern air travel technique where, of course, parachutes are not provided for every passenger.

History tells us that in a majority of evacuation incidents the personnel concerned would have been safer to have remained on board. I also dread the idea of a diving bell or compression chamber being cast adrift in North Sea weather conditions. These pressure vessels are not designed for this. Perhaps, in the long-term future such a technique might be entertained. At present our main effort should be concentrated on prevention.

The proposed technique of transferring a casualty from offshore to a pressurised hospital onshore is another matter that is taking up much of our time. The medical world supports the concept and would like any doctor going offshore to attend a "civil engineering type accident under pressure" to have the choice of dealing with the patient in the chamber on the rig or transferring him under pressure to better facilities. Unfortunately, the engineering involved is not simple, the space necessary is not always available and the cost, not only of transferring a patient, but continuously maintaining a hyperbaric hospital operating theatre and all the associated medical teams in deep diving practice is not cheap. One also has to consider the high pressure nervous syndrome problem that may be encountered by the medical teams.

The consideration of all these problems leads us to the action that can be taken at present. The first need is to maintain life. This may require resuscitation, control of bleeding, injections, etc. Under saturation or long decompression situations immediate first aid can only be given by the divers themselves.

The arrival of a medical doctor can, in the North Sea, take from 2 to 6 hours. In other parts of the world it could take days. The doctor then has to go under pressure and, depending on the depth, speed of pressurisation and the doctor himself will depend how long, having reached bottom, before he can be of any use. This leads me to the firm conclusion that <u>ALL DIVERS MUST BE HIGHLY TRAINED IN FIRST AID AND KEPT IN TRAINING</u>. This should be a minimum requirement. If the diving team contains a para-medic, if the rig medic is also a diver, if all the divers can set up a drip etc. these are all bonuses. One must face the fact that it is going to be the divers themselves who provide that very important initial medical care.

I am at least pleased to tell you that civil engineering type accidents and trauma with divers is minimal.

In the United Kingdom it is the duty of the employer of divers to secure that arrangements are made under which emergency services, at all times while diving operations are being carried out, are able to proceed, by the most suitable fast forms of transport to the location of the operation in the event of an emergency which threatens the safety, health or welfare of any divers. Within the next few months a centralised diving medical emergency service will be established in the United Kingdom.

It is quite unnecessary for me to repeat the statement that diving is a hazardous operation and that diving in the offshore industry is even more so.

One could of course, make diving absolutely safe by stopping it. However, it is one of the hard facts of life that no machine or technique has yet been designed or invented to replace completely the human under water.

The question then arises, for whose protection should diving regulations be designed? There is absolutely no doubt in my mind that diving legislation, and the diving inspector's task to ensure that the legislation is implemented, is for the safety of the diver, a man under water first and foremost. It is also another hard fact of life that the interface between the Diving Inspectorate, the operational diver and the diving companies must be very close. From our experience of operating the offshore diving regulations for the last 3 years it has become obvious that close liaison with the diving companies and the divers themselves is essential. We have also found it essential for the diving inspectors to have a sound background knowledge of all types of diving and that they keep themselves up-to-date with the new techniques which are being introduced almost daily. This rapidly expanding technology also requires flexibility in legislation to permit the introduction of new and often safer diving techniques. We have found that the power to provide exemptions from certain parts of the regulations is absolutely essential.

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APPEALING...OR APPALLING?

Professor Carroll Wilson, former general manager of the US Atomic Energy Commission and now at the MIT, said in Sydney recently that there was a plan to dump atomic waste on a Pacific Island. So far no island had been chosen but it would need to be one far from habitation and earthquake zones and acceptable to the major powers (he didn't mention lesser powers!). The waste would need to be heavily protected and regularly checked and be placed either in the ground or in, say, 15 metres of water to act as a radiation shield. He found the idea "immensely appealing". While this is possibly an advance over previous dumping in the Mediterranean and into Atlantic canyons or down into the deep water strata in America, it will be regarded as a possible Health Risk by many who are ignorant of the benefits of radiation in the food chain that originated in the Oceans. Still, we can take comfort in the words of Professor Willard Bascon, quoted in a newspaper report as a "research engineer and pioneer scuba diver". "You can't pollute the ocean. There's too much of it. You can barely add enough to detect, to say nothing of damaging it". He then said that frantic cries that the seas are dying resulted from television productions more inclined to drama than fact.

Perhaps Cousteau and the others need a course in marine ecology ...

THE HISS OF LIFE?

When Adelaide reptile farm owner Joe Bredl transported some of his specimens in sacks in his truck he forgot that the term "peer group pressure" could be translated to mean that those at the bottom of the pile get squashed.

He was dismayed on arriving at his destination to find that his favourite taipan, the deadliest snake in Australia, had seemingly expired. Never one to fail a friend in need, Joe pushed a straw down the snake's windpipe and revived it by EAR methods. Could you successfully resuscitate a friend?

SAFER SURFACING

Dr A G Slark

> *"What time is high water?"*
> *"Haven't a clue."*

This exchange between two divers, both boat owners at that, typifies the attitude of too many towards the sea. Ignorance and lack of concern for the basic information about the intrinsically hostile environment which divers wish to enter is a continuing cause of accidents.

Every year, more people take up diving without having previously been involved with any other water sport. Furthermore, the increasing professionalism of diving instruction tends to promote the early acquisition of sophisticated and expensive apparatus without any 'apprenticeship' in the free diving. These trends will develop a generation of divers of whom many will be less conversant with the moods of the sea.

Diving fins and suits give an insulation from cold and manoeuvrability and speed in the water which compares most advantageously with the swimmer not so well equipped. This inevitably leads to an exaggerated impression of capability in the water, although swimming speed is still very slow in real terms. For instance, the speed of 1 knot is near the maximum average sustainable. This is about 30 metres per minute. The speed of 40 metres per minute cannot be kept up by the average diver for more than a very short period.

These figures are for divers without the encumbrance of apparatus. An inflated buoyancy compensator will diminish this swimming speed. A sack of crays or scallops will reduce it much more. The significant point about this is that tidal streams of 1 knot or more are very common throughout New Zealand. Furthermore, as the speed varies by the hour, it is possible to enter the water on a slack tide and emerge when there is a greater set than can be swum against. Also, the maximum stream varies day by day, so that what is completely safe during neap tides may be highly dangerous during spring tides. The places which divers are likely to find most interesting to dive at are also those places which experience strong tides. Tidal effects are greatest off rock promontories, particularly if the rock faces are steep. Rock pinnacles and archways will also funnel the tide. Another factor which has to be borne in mind is that on the bottom the tidal effect is much less than on the surface, so that the diver's maximum physical effort may be required when he has completed his time under water and when he may be most tired.

Recently, a diver was admitted to the RNZN Hospital suspected to have been suffering from a bend. She stated that she had been diving to about 70 feet for nearly half an hour and, following the dive, had needed to swim for 30 minutes to get back to the boat. She was not found to be suffering from a bend, but was in a state of complete physical exhaustion. This is hardly surprising in view of the very considerable effort which she had been faced with throughout her diving. It must also have been associated with a great deal of anxiety. She made it back, but only just.

This time last year, a diver under somewhat similar circumstances, did not. His body was recovered on the bottom after his buddy had swan back for assistance to the boat - which was obscured from vision, on the other side of the headland - after they had surfaced from their dive, feeling very tired.

Although a diver's swimming speed is small, the distance covered during a short dive may be quite sufficient to take him beyond the range of vision of his support vessel.

There are few of us who have not at some time or other sat in a boat, anxiously scanning the distant horizon for two small heads one had last seen entering the water some 40 minutes before. Likewise, most of us have had the experience of surfacing behind a support boat which seems to have sailed without its most important passenger.

Diving in a tideway, or upon a submerged reef, adequate surface support for a diver is of even greater importance. Furthermore, if divers are likely to be carried away from the support boat, some method of increasing the visibility on the surface should be carried. In the Navy, all divers have a smoke and light-flare attached to their diver’s knives, which is replaced periodically to make sure it is functioning when necessary. Although such a system may not be suitable for an amateur diver, some form of inflatable buoy or small flag in rescue orange could easily be carried by the diver in such a way as to increase his visibility on the surface. I have noted that divers also tend to over-estimate how readily they may be seen on the surface. In addition, light conditions and the state of the surface water may change quite dramatically during the course of even quite a short dive.

Records of diving accidents reveal repeatedly how important the interval between surfacing and getting back aboard is. If prolonged, any disorder provoked during the dive will be exacerbated. The chances of becoming bent, for instance, are greatest immediately after surfacing, and are increased by strenuous exercises such as swimming. Furthermore, none of the diving tables were designed or tested with such a pattern of activity in mind. Greater risks, therefore, are taken by the diver who enters the water from the shore, using scuba apparatus. Yet this is just what the novice may rush to do with his brand new gear. All divers, both veteran and novice, must dive within the limits of their capability, both with regard to experience and physical fitness, and relate these qualities to the conditions likely to be experienced when back at the surface.

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<u>EXERCISE, LIKE SEX, SHOULD BE REGULAR, SAYS DOCTOR</u>

Dr Harry Lander, at the University of Adelaide, has spoken up after a couple of health-seeking joggers fell dead after their exertions recently. He said that a lot of people are seen in the Adelaide Hospital who have discovered that they have pushed it too far. The most strenuous exercise most people take, he commented, is regular breathing. He added “it’s the same with sexual intercourse, you’ve got to keep at that, otherwise you can drop dead there too”. He gave his exercises as breathing and flying.

Naturally the National Heart Foundation doesn’t accept this defeatist talk. Dr John McPhie, Medical vice-president, replied that “there is ample evidence that people who exercise have a lower incidence of heart attack. The sudden death of a 25-year-old can happen in front of the television just as easily as while jogging. It depends on whether there is an existing predisposition.”

It is not certain whether divers let all aspects of their health become neglected, but it is best to keep the above advice in mind ....

SEA SNAKES, A CONTRAST TO OTHER VERTEBRATE DIVERS

Harold Heatwole

Sea snakes have a maximum capacity of diving to 100 metres depth and remaining submerged for two hours, after which they can rise rapidly to the surface, take only 1-3 breaths and then return to the bottom. Despite the depth and duration of submergence, they do not become anoxic, contract an oxygen debt or suffer the bends (Heatwole and Seymour, 1975 a ,b, 1976, Seymour 1974, Seymour and Webster, 1975, Heatwole et al., 1977). The means whereby such diving feats are possible would seem to be of interest to specialists in diving medicine and consequently are outlined in the present paper.

Although there are special adaptations involved in the diving physiology of sea snakes, there are certain characteristics of the general reptilian mode of life which differ from that of mammals in ways conducive to long periods under water. The chief of these is ectothermy.

Reptiles rely primarily upon external sources for body heat. Their body temperature may merely approach that of the external environment and fluctuate with it, but more often there are behavioural means (such as basking, shade seeking, etc.) of maintaining it within a certain range (Heatwole 1976). Although a variety of physiological, especially cardiovascular, adjustments aid in maintenance of body temperature (White 1976), endogenous production of heat is not a very important factor. Much of the food energy consumed by endotherms (mammals and birds) goes into chemical thermogenesis and the maintenance of a relatively high body temperature. Consequently, they have a high metabolic rates in comparison to reptiles which do not have such an energy requirement. It is for this reason that reptiles can go weeks, or even months, without food and not suffer nutritional problems. In general, the resting metabolic rate (and the resting oxygen consumption) of reptiles is only about 14-29% that of a mammal of comparable size (Figure 1: Bennett and Dawson 1976). In diving terms, this means that a reptile could be expected to remain submerged 3-7 times as long as a similar sized mammal on an equivalent amount of air before becoming anoxic, or requiring special mechanisms such as anaerobic glycolysis. This effect is further enhanced by the fact that reptiles have larger lung volumes than do mammals of equivalent size (Figure 2: Wood and Lenfant 1976). Combining the effect of low metabolic rate and large lung volume, the advantage a reptile would have over mammals in terms of aerobic diving time would be many fold, even without any social physiological adaptations. It would appear that even most land reptiles could be accomplished divers if they chose to do so. Indeed, a variety of species that are otherwise terrestrial or arboreal will jump into water and submerge for long periods as a means of escaping predators or man (see Heatwole 1975). In many aspects, sea snakes do not show any modification of the general reptilian plan. For example, the metabolic rate of sea snakes is not lower than that of an equivalent sized land snake at the same body temperature (Heatwole, in press). Similarly, the haemoglobin content, blood oxygen capacity, oxygen dissociation curve, degree of Bohr shift and other blood characteristics of potential importance to divers does not seem to differ markedly among sea snakes and land snakes (Heatwole and Seymour 1976, Heatwole in press).[1]

There are several ways, however, in which sea snakes differ from land snakes that would seem to be of advantage to the diver. The lung of most snakes is a simple tube. The anterior region (really an expanded trachea known as the “tracheal lung”) and middle portion (bronchial lung) are highly vascularized and are involved in exchange of respiratory gases. The posterior portion (Saccular lung) is membranous and receives only nutritive blood vessels. Consequently, it is not involved in respiratory gas exchange. Surgical ligating and deflating of this portion decreased the voluntary submergence times in sea kraits whereas it had little affect on locomotion or ability to move upward or downward in the water (Seymour and Heatwole, in press) suggesting that its prime function is respiratory (perhaps air storage) rather than buoyancy control. Land snakes have respiratory problems (during prolonged swallowing of large prey, or when buried in sand) and the above lung structure is not unique to sea snakes. However, lung volume seems to be larger in sea snakes than in terrestrial species; often the lung extends from the neck to the posterior part of the body cavity.

The main physiological diving adaptation that sea snakes have is the degree of cutaneous respiration.[2] Land snakes have a very low rate of cutaneous gaseous exchange, and only a small proportion of their respiratory requirements are met in this way. In contrast, in sea snakes as much as one fifth or in some individuals one third of the resting oxygen requirements can be met by uptake through the skin and most if not all of the CO_2 can be eliminated via this route (Graham 1974, Heatwole and Seymour 1975; a,b, 1976).

Because of the combination of cutaneous respiration, large lung volume and low metabolic rate, sea snakes can remain aerobic under water for long periods of time. Seymour and Webster (1975) have shown that during extended voluntary dives snakes remain aerobic and do not produce much lactate. Indeed, sea snakes are just as sensitive to anoxia as are land snakes and lizards and are much more sensitive then are freshwater turtles (Heatwole, in press). Only in emergencies (ie. when forced to remain under water longer than the voluntary submergence time) do sea snakes resort to anaerobiosis.

Cutaneous gas exchange is not only important directly in respiration, but has implications for a number of other aspects of diving. For example, loss of CO_2 via the skin means that it fails to replace the gas volume lost through utilization of lung oxygen and thus snakes decrease in buoyancy with increased submergence time. Similarly, one of the major influences preventing the bends is probably the loss of blood nitrogen directly to the water via the skin.

One of the most important effects of cutaneous respiration is that it alters the significance of the circulatory system in diving. In order to understand this relationship it is necessary to contrast two major modes of circulatory adaptation to underwater life.

Most vertebrate divers (including mammals, birds and perhaps some reptiles) respond to submergence or apnea by (1) vasoconstriction of the peripheral and splanchnic vessels, resulting in (2) anaerobic glycolysis during which accumulation of lactic acid occurs, and an oxygen debt is incurred which must be paid back during breathing at the surface. Accompanying this is (3) bradycardia with the blood-flow circuit reduced to serving vital areas such as the heart and brain (Andersen 1966).

As indicated above, the last is characteristic of sea snakes only in emergencies; usually they produce very little lactic acid, remain aerobic throughout their dive, and do not breathe at the surface long enough to dissipate an oxygen debt. Although there are heart rate changes during the diving cycle. Heatwole (1977) has pointed out that they are not associated with the rest of the above syndrome and consequently they cannot be considered as diving bradycardia. Rather, they represent brief elevations of heart rate just prior to and during breathing (breathing tachycardia) which results in rapid lung perfusion and gaseous exchange during ventilation.

Cutaneous gaseous exchange would seem to be incompatible with the above syndrome because of the opposing demands for perfusion of peripheral tissues.

For cutaneous respiration to be effective, the skin must be perfused and peripheral vasoconstriction would be a disadvantage. For peripheral anaerobic glycolysis and husbanding of lung oxygen for vital centres, vasoconstriction is essential. Most vertebrate divers seem to respond in the latter way whereas the sea snakes have opted for the former strategy.

The circulatory system of reptiles also plays another role in diving. The reptilian heart is unique in vertebrates in that (1) there are two separate systemic arches leading from the ventricle, and that (2) the ventricle is divided into several subchambers which can communicate with each other at least under certain conditions and at certain points of the heart beat cycle. Alteration of intracardiac pressure relations result in some of the systemic venous return bypassing the pulmonary circuit and leaving the heart via the left systemic arch (right-to-left) shunt).[3] Thus a reptilian heart permits a flexibility of function lacking in the mammalian heart in which the systemic and pulmonary venous returns are mandatorily completely separate.

In terms of diving4, the significance of such shunting is probably that low perfusion of the lung, when submerged, results in a gradual uptake of lung oxygen over a long time without a large elevation in blood oxygen levels. The lower the blood oxygen level, the greater would be the oxygen gradient across the skin and the more effective would be cutaneous oxygen uptake, and the greater the proportion of the total oxygen requirements that would be obtained via the skin. Also, a low perfusion rate of the lung would result in a reduced rate of nitrogen uptake from lung air and would decrease the risk of bends.

In summary, the reptilian mode of life with its associated ectothermy, low metabolic rates, large lung volume, and functionally flexible heart has in a real sense been a pre-adaptation for a diving existence not enjoyed by mammals. In sea snakes, development of cutaneous respiration has served to enhance those basic characteristics and has resulted in a different type of circulatory response to diving than that found in most divers; cutaneous respiration is also related to buoyancy control and prevention of the bends.

Footnotes:

1 By contrast there are some aquatic snakes of the family Acrochordidae that do have a greater Bohr shift and a lower metabolic rate than do land snakes or sea snakes.

2 There are also a variety of morphological adaptations such as paddle-shaped tail, nostril valves, and valves forming a tight seal when the mouth is closed. Also, a major adaptation to the salinity conditions of the sea is a salt excreting gland under the tongue which aids in osmoregulation (Dunson 1976).

3 The right systemic arch carries blood to the head as well as the body and tends to receive primarily oxygenated blood at all times. The left systemic arch supplies the posterior body and when oxygenated and unoxygenated blood is mixed it tends to exit from the heart via the left rather than the right arch (see Webb et al. 1971 and White 1976 for a detailed discussion of the anatomy and blood flow pattern of reptile hearts). During ventilation, perfusion is sometimes enhanced by a left-to-right shunt.

4 The significance of such shunting also lies in the ability to alter the heat transport function of the blood during basking and other thermoregulatory behaviour and still maintain oxygen transport capabilities (see White 1976).

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SPEAEOLOGICAL DIVING IN THE UK - SOME PROBLEMS AND FATALITIES

(This article is based on reports printed in the Cave Diving Group Newsletter and made available by Dr Oliver Lloyd. The Editor)

The type of diving undertaken by members of the Cave Diving Group bears no resemblance to that undertaken in the Florida or Mount Gambia freshwater shafts and caves. The first and most significant difference lies in the motivation, the second in the type of spaces entered. These people are intent to continue their exploration of underground passages beyond the point where a water block is encountered and regard their breathing aid as a tool for this purpose. They are not, it would appear, divers who are desirous of a new experience but cave explorers who refuse to be thwarted. They hope to find new caverns or establish a physical communication between different underground water-formed passages. They are, hopefully, used to making a cold wet, dark way through narrow passages where their personal skill and expertise is constantly under test. Though a certain reliance on others may be present the most successful have been described as “thrusters”, a personality trait that may assist survival under difficult circumstances yet predispose to an early death. Accidents in this sport, as in general, are frequently the result of a number of factors occurring sequentially with unpleasant consequences. That such “divers” suffer fatalities is less surprising than the undoubted fact that so many survive! The stress limits of the human body, and spirit, are high indeed. The naming of one locality “the Rectum Passage” may indicate to readers something of the flavour of this sport and recreation.

In 1964 the Cave Diving Group (CDG) newsletter published suggested guidelines for their members. It was advised that there should always be a stand-by diver ready at base to offer assistance, that the diver must have a line connection with his base and have a 100% safety margin of air. Time and experience have shown the impracticability of the first when exploring narrow passages, for there is no way in which the second diver can give the leader assistance. It was suggested that diving be by pairs, a spare breathing set be carried and two-way telephone speech communication be set up between diver and base. Only the second suggestion is honoured, and then only when specially long dives are planned. There is a high risk of grit entering the mouthpiece of the reserve set, one cause of downstream valve leak. The limitation of the buddy system was illustrated by a quoted case where the first diver was slimmer than his companion. This diver squeezed through a narrow opening and then suffered a downstream valve leak. Luckily, although only a trainee, he was able to control it by having one hand on the bottle tap: lucky, for the instructing diver could not get past the narrow section. Self reliance is indeed a necessity!

The first attempts to pass water barriers were by breath-holding duck-dives, a form of heroism most would eschew. The introduction of small scuba air bottles to civilian uses enabled longer barriers to be forced. Such air sets are often hand-held, for there is often too little room for the diver himself, let alone one wearing a tank and backpack. The personality profile of anyone who wishes to undertake this type of risk will rarely include a liking for regimentation, so it is not surprising that many appear to learn by experience rather than through the slow-but-thorough methods of the BS-AC. It is arguable that they intend a somewhat different use of their diving skills and are in fact constrained so strictly by their environment that they are bottle users rather than scuba divers. Nevertheless at least one of those killed was a qualified and experienced diver as well as being one of the most admired cave divers of these days. The following Incident Reports illustrate that notwithstanding the differences, there are similar general safety principles operative as in open water diving.

Case 1 Alan had 6 years of cave exploration experience but this was his very first attempt to dive. He bought his gear on the Friday afternoon and on the Saturday afternoon jumped into Keld Head, lost the line after 30 feet and came out very shaken (125 ats down to 110 ats). He had a fag with his mates and went in again. Movement on the line was felt for 20 minutes. After 30 minutes the *CRC was called. Th*ere were no cave divers present but there were two sub-aqua types there who went in for about 30 feet to look. Wooding was the first active diver there and he immediately checked the first air-space. The line was very slack and had got very tangled. He prepared for a second dive and found on checking that the line was in fact dead slack, so pulled it out. The end appeared to have been freshly cut with a knife, but this was not certain. He then dived on the old line, which ended up in the first air space again. Despite prolonged searching by several divers the body was never recovered. The victim was aged about 21 to 24 years.

Case 2 Steve had the unfortunate honour of being the fourth drowning in this cave (Perth yr Ogof). He was one of a party of four University students which approached the resurgence from within the cave. Only the leader was wearing a wet suit. He and No. 2 decided to swim through the resurgence, while No. 4 decided not to. It is not certain whether No. 3, the victim, had decided to swim or not. It is not known whether he could swim. When Numbers 1 and 2 had emerged they looked back and saw the light of No. 3 under the archway in about 15 feet of water. No. 1 tried to reach him but the buoyancy of his wet suit prevented him from diving sufficiently deeply.

The alarm was given and some members of the CDG, who had been diving in another cave, arrived about 50 minutes later. One donned weight belt and mask and reached the Steve’s body, tying a line to an ankle. He was lying in clear water on his right side, facing upstream. There was no entanglement. The victim, aged about 19 years, was wearing old clothes, a boiler suit, a good helmet and an Edison cell for light. He had been down a cave once previously.

Case 3 This victim, Paul, was a 19 year old University student who excelled at all water sports and was a particularly good swimmer. He had achieved the Diploma of the Royal Lifesaving Society and taken up diving about three years ago, logging a total of over 80 dives. He was President of the Underwater Club at his University at the time of his introduction to cave diving. His underwater confidence is attested to by two incidents; in the first he managed underwater vomiting in a calm manner, while in the second he made a successful return after following tangled lines up a blind passage underground in nil visibility. In the few months he cave-dived (August 1970 till February 1971) he became recognised as an outstanding Cave Diver, experienced in solo exploration under difficult and extremely adverse conditions. The fatal dive was made only after careful briefing, but he made one mistake. He started upstream using a single 40 cu ft bottle with an empty line reel to take in loose lines which abounded. He committed the error of having the line he was following, which would have led him home, for one whose upper attachment had come loose (or been cut loose by vandals). He apparently had used most of his air before realising the line was not leading him to an exit. When found he was still in a swimming position, holding the line with his left hand and with the mouthpiece firmly held in his mouth. He was still in this position a week later. The force of the current and the narrowness of the passages made body recovery impossible.

Case 4 Shaq is reported to have been a very good swimmer and to have done some open water diving. His cave diving experience however was quite small and he was possibly pressing his luck in at tempting a difficult sump ... but inexperienced divers by definition cannot know their limitations and unless they are pushers will not reach them. Apparently he had dived into an unexplored tight static sump at 3 pm, leaving his “sherpas” at the entrance. They received three line pulls, to say that he was through, after 15 feet of line had been used. The line was tied round his wrist and base fed. He did not return and the line appeared to be tied off so in due time the alarm was raised. He had entered the sump feet first, without a weight belt because the passage was extremely tight. The body was reached some five hours later - a task requiring thrutching while holding a 60 cu ft bottle. It was 15 feet in, mask and mouthpiece out of position, lying face up with mouth closed. The bottle, a 14-20 cu feet fire extinguisher type one, was empty. It was stated later that the demand valve had a ruptured diaphragm, though this is questioned. His light and helmet were missing so it is surmised that his light had failed after passing the sump, for “it was a bit dodgy when he went in”, and he had attempted a return in the dark. As he was under weighted he may have scraped the roof and lost his mask, an unsettling occurrence even in an experienced swimmer. The line was attached to his wrist at the time of recovery.

<u>Case 5</u> Roger first became interested in cave exploration in 1962, an interest that developed greatly and extended into cave diving when he later went to University. He organised many difficult surveys of cave systems and it was in furtherance of this activity that he died. The dive had been carefully planned and all the equipment brought up in preparation for an attempt to force what appeared to be an easy sump. Both divers involved were highly experienced and used to working together. They took three cylinders each, a line reel and a pair of boots. The tads were deposited in the airbell between sumps 2 and 3 for use on the dive out and they then continued into sump 3 with full bottles. Their progress was uneventful. After donning the boots an arduous way was made along an often deeply incised, narrow and watery trench in the floor of a large passage. Half an hour later the objective, sump 4, was reached. It was decided to dive together, yet independently if at any point either diver felt uncertain and wished to turn back. They swopped main valves onto two full bottles, retaining the others in reserve. Roger had two positively buoyant bottles, and was underweight, while his companion’s were negative. From here on they were in previously unexplored territory.

Roger set off first, laying the line from a 400 foot reel while the other followed a few feet behind with a 1,000 foot reel. The passage was spacious, about 20 feet wide and 10 feet+ high; visibility was 12 feet. The dip, in excess of 50 feet, was clearly noticeable at the sump pool and was maintained if not increased within the sump. On several occasions Roger had difficulty in clearing. At the end of the reel the depth was estimated to be 50 feet and showing no sign of surfacing. After consulting his gauge the second diver tied on the second reel and assumed the lead. Roger at this point cut his reel free from the line and attached it loosely via a short “jump line” back to the line. After about 100 feet a sharply ascending gravel bank was encountered. The passage here was about 10 foot wide and 5 foot high. A glance at the rear showed no sign of Roger but a little later he was seen and contacted and the signal given to start the return. The buddy reached the pool safely and was then incapacitated for a time with an acute head pain. The failure of his friend to return gave him alarm, especially when he found that the line had become slack. The line pulled out easily and it was seen that it had been cut at a point 30 feet beyond the junction of the lines and no longer had any reel attached. Feeling shocked by this discovery the survivor made his return to the surface, finding that nobody had remained at base. A search was then organised in the hope of finding the body, with only the faintest chance that Roger had survived in an air pocket. However no trace of the victim was found.

Case 6 A multiple tragedy occurred when a party of six cavers who had gone down Langstroth Pot, abseiling the pitches, attempted to exit by the three sumps in Langstroth Cave. These sumps are first, going downstream, one that starts at the foot of the last pitch (5.5 feet), then there is a short canal and the second sump (8.5 feet) and the third (11 feet). Between these, well over to the left, is an air bell in which the line is belayed. This measures 7 feet long x 2.5 feet wide x 4 feet high and has 3 feet of water. This air bets quickly used up by divers.

The leader of the party dived first and had some trouble locating the line in this air bell. He thought he was being followed by the others, so when no body came he gave the alarm. The Rescue and Recovery party located one body 8 feet inside sump 3 and a second just beyond. A third body was found in the small air bell, face down in the water. The rescuer, a Wallbank, dived yet again, expecting to find more bodies in the other two sumps; he was immensely relieved to find the other two cavers waiting at the bottom of the final pitch. Supplies were ferried through to the survivors to cover the time until the sumps could be pumped dry. The fifth diver had been pulled back by the last of the party when he was observed to be in difficulties with his attempt to reach the air bell. The rescuers noticed that the “bell” air tasted foul when the victims were reached.

Case 7 A CDG member on holidays in Spain was lost in a downstream sump. This was situated about 600 feet underground, 3/4 mile from the cave entrance. The victim apparently suffered an underwater blackout, it is presumed, in passing this 4 foot high x 10 foot wide sump. His line reel was found 150 feet beyond the obstruction. His buddy made unsuccessful attempts to locate him in the nil visibility conditions that prevailed, and later searching was no more successful.

These cases cover the 1971-1976 period and involve persons in no way related to the CDG in addition to their members. The CDG is alert to the need for assistance in case of underground accidents to cavers as well as to their own members. They have retrieved the body of a boy lost from a party and drowned in an underground lake, and ferried equipment and a stretcher to a caver who suffered a fractured pelvis, giving aid while the sumps were pumped dry. They have even persuaded “volunteers” to submit to being passed through a sump with “rescuers” holding the air bottle for the “victim” in the carrying sheet. Six feet must have seemed to stretch forever, for one of the volunteers had never dived before!

Dr Lloyd has commented that the cases illustrate that a number of factors seem to play a part in determining the fatal outcome, instancing cases 4 and 5 in particular. Shaq had little experience, and it is only with experience that little troubles can be overcome early and prevented from becoming big troubles. He lost his mask, he was underweight, the sump was tight. It is not comfortable to turn upside down and crawl along a roof as water in the face mask then runs all over the face and the valve doesn’t deliver air so easily. In Roger’s case there seems to have been a succession of little troubles: he was underweight, he had sinus clearing problems and finally he must have had a line problem, for he cut it.

Cavers and cave divers face risks few others would accept “for all the tea in China”. Their bravery is unquestionable. Perhaps it is too great on occasions.

APPENDIX A - SUMP AIR

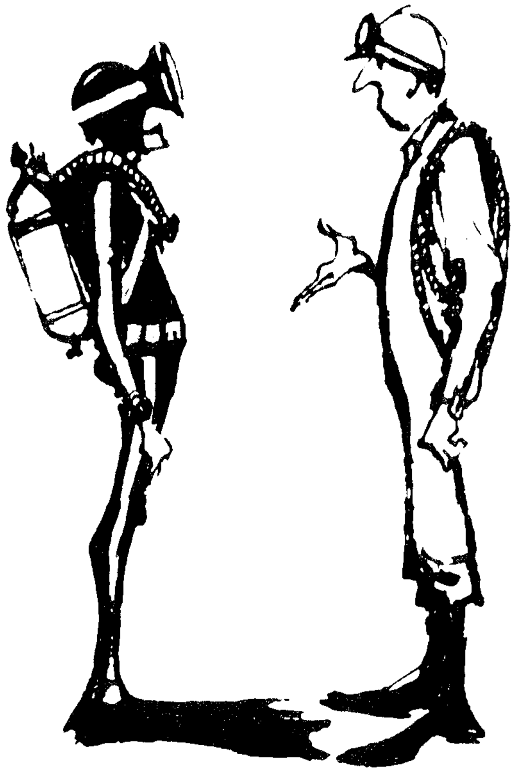
It needs to be remembered by all sumpers and not merely cave divers that sump air has a different composition from fresh air. Although it contains more (33%) oxygen it also contains a very high proportion of carbon dioxide (2.9%). This is because sump air is in equilibrium with the air dissolved in the water. Therefore the gases are present in proportion to their solubility in water. Oxygen is more soluble than nitrogen, but CO2 is very soluble indeed and is present in a hundred times as great an amount as it is present in fresh air. When the CO2 level exceeds 3% it gives rise to discomfort. Where it rises above 5% it can make you flake out, regardless of how much oxygen is present. There is no question of the air being "used up". What happens that it gets poisoned with a lethal concentration of CO2.

APPENDIX B - SUCCESSFUL APPLICATION OF EAR TRAINING

A member of the CDG wrote to thank Dr Lloyd for the training in lifesaving he had received. The following incident report illustrates, in a possibly extreme form, some of the problems that may face the first aider:

"We were canoeing on a river and stopped for a quick beer. Suddenly on the other side there was a commotion and I saw them dragging a body out. I swam over and found about twenty youths just hitting the body around the face. That, I guess, is the one thing that one doesn't face in training, the difficulty of dealing with a number of panic stricken friends and relations. The victim had been under for between 5 and 10 minutes: no breathing; heart stopped (I actually remembered the signs); blood, water and mucus was pouring from his mouth. That is another thing that training cannot prepare you for, the sheer horror of being in that situation and how to prevent yourself vomiting while doing mouth to mouth. I managed to get his heart started and used a Holger-Nielsen respiration. He started breathing all right but didn't come round (do people normally regain consciousness quickly?) I then found that he had drunk a pint of 151 proof spirit before entering the water. It took half an hour for the fire service ambulance to arrive and when they did come they didn't seem to know what to do. Drowning and alcohol poisoning aside, he seems to have pulled through ... thanks to the instruction I received at the pool side in Bristol. I was surprised at the ease with which his heart restarted and his breathing came back. It's encouraging to know that these things really work, for I always had my doubts in training and the last time I had to do it for real the guy didn't recover.

Sincere congratulations are offered to the person making the above report.



"However can you dive, dressed like that ? '

SUBMERSIBLES - MANNED AND UNMANNED

Dr Victor Brand

In 1716 Sir Edmund Halley, who discovered the Comet which bears his name, built a diving bell which could support divers working at 65 feet for up to 4 hours.

It was not until the 1930's that William Beebe developed a diving vehicle which he named "Bathysphere". It was built of quarter inch steel and was 4 and a half feet in diameter. Oxygen was fed into the sphere at the rate of 2 litres/minute to cover the requirements of two persons. This bathysphere made 32 dives between 1930 and 1934, and reached a maximum depth of 3028 feet. These dives are described in Beebe's book "Half Mile Down" - a classic of the underwater scene.

Then Professor Auguste Piccard transferred his attention from the stratosphere to the inner space and his first vessel FNRS-2 proved to be the first of the modern submersibles in that it was not secured by cable to a mother ship and had its own means of propulsion, ascent and descent.

He later built the "Bathyscaphe Trieste" which in 1960 reached the deepest known depth in the ocean, 35,800 feet in the Challenger Deep in the Marianas Trench. In the 1960's, interest in underwater exploration using diving vessels became intense. The following is a short summary of some of the useful work which was done in this period:

1958 Cousteau's "Soucoupe" 1000 feet capability.

1963 "Trieste I and II" recovered some remains of the "Thresher" submarine which sank off Boston. The sub was first discovered and photographed by "Mizar", a naval research ship which towed an underwater camera platform.

1964 "Archimede" a French Bathyscaphe which reached 34,500 feet in the Kurile Trench near Japan.

1966 "Pisces", a Canadian vessel, raised a sunken tug boat from 670 feet in Pugot Sound.

1966-70 "Pisces" was used to recover Naval experimental torpedoes.

1968 "Star II" located and recovered nuclear payload from an aborted satellite launch.

1969 "Mizar" located wreckage from Nuclear sub "Scorpion" near Azores, "Trieste II" inspected and analyzed the remains.

1970 "Mizar" located lost French sub "Euridyce" near Toulon and "Archimede" investigated the wreckage.

1970 "Deep Quest" located a fighter plane in 3500 feet off San Diego.

1966 H Bomb at Palomares, Spain. After 2 planes collided, 3 bombs were recovered near the village; the fourth was eventually located at 2800 feet by the submersible "Alvin". Two parachutes attached to the bomb were waving about in the swell and after becoming entangled, "Alvin" backed off, while the unmanned "Curv", cable controlled underwater recovery vehicle, attached a line to the bomb.

It is clear that much of the important underwater salvage has been achieved by unmanned craft. During the Symposium of underwater physiology in 1975 organised by the UMS, a paper titled “Why Man?” was read by HR Talkington. The speaker pointed out the limitations of manned craft.

1. Personnel fatigue
2. Waste disposal
3. Life support systems
4. Fire safety
5. Escape
6. Personnel training

The unmanned vehicle is not affected by these considerations.

New technology in low light TV systems, manipulators and feed back control systems has resulted in a very functional craft which can be much smaller and cheaper than the manned submersible.

Hybrid vessels are being designed and produced with diver lookout facilities, and carrying their own unmanned vehicle for use in special circumstances.

The October 1976 issue of the journal *Ocean Industry* contains a directory of 63 unmanned vehicles in use, under construction, or in the design stage.

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AVIATION SAFETY, WINGED AESCULAPIUS

It isn’t every day that an invitation comes to join a class of pilots on an air medicine course. I arrived just in time to enter the compression chamber and “go up” to 24,000 feet before taking off the oxygen mask to learn the feel of oxygen lack, to be recorded by pencil on a pad .... nearly illegible before oxygen was resumed.

Everyone talks flying all the time. We saw a lot of films ... how to survive on a tropical island; when and how to use a variety of ejector seats (they never practice using them, as crush fractures of lumbar vertebrae are a real hazard).

The old pilots (in their thirties) speak critically of the younger generation. “We worked hard to ensure success. Now they don’t care if they’re scrubbed; they go and do something else. And it’s no use threatening young student pilots that they’ll get killed if they do the wrong thing. In these days of disposables and inbuilt obsolescence they don’t fear death ... so they are taught it will <u>hurt</u> before they die; then they pay attention.”

We learned of noise hazards, about spacial disorientation and about night vision. Good pilots are encouraged to lead almost monastic lives. Wine, women and song are all bad news before flying.

(Extracted from an essay by “Hypophysis” in AMA Gazette, 4 August 1977)

DIVING SAFETY MEMORANDA NO 11/1977 - TRANSFER OF A DIVER UNDER PRESSURE BY HELICOPTER

Commander SA Warren, Dept of Energy, UK

International Underwater Contractors (IUC) have developed a system to allow the transfer of divers by helicopter under continuous pressure from an offshore installation to an onshore decompression facility.

This transfer system has been developed for divers working in the North Sea and has recently been demonstrated successfully. It is capable of transporting an injured diver from an offshore situation to a large compression chamber onshore where medical teams can treat and monitor a diver's condition in clinical surroundings and in close proximity to a major hospital.

Under some sets of circumstances it could be used in the rig abandonment role. The large helicopter chamber being capable of containing up to eight persons.

This system is available in the United Kingdom now.

It is recommended that diving companies ensure, wherever possible, that their diving chamber complexes are sited in such a position that provides the necessary space for operating the transfer under pressure system and that where necessary the adaptor spool pieces are made available.

International Underwater Contractors (Scotland) Ltd will make available drawings of the mating flanges of the chambers to anyone in the industry who cares to check the compatibility of their own installations. Additionally, Comex of Aberdeen has indicated that they would be willing to manufacture spool pieces for systems where adaptation is required and supply these spool pieces at cost.

The physical dimensions of the transfer chamber are:

Length overall	7 ft 8 ins
Diameter including handles	2 ft 8 ins
Width of detachable trolley	3 ft 8 ins
Minimum distance from deck to bottom of flange	4 ins
Maximum height with trolley removed	2 ft 9 ins
Maximum height on trolley	4 ft
Weight equipped but unmanned	550 lbs
Weight of trolley	84 lbs

Dimensions of helicopter chamber:

Length overall with clamp	8 ft 6 ins
Wheel centres front to back	3 ft 8.5 ins
Wheel centres left to right	26.5 ins
Minimum distance from deck to bottom flange	15 ins
Horizontal distance flange face to front wheels	2 ft 6 ins
Maximum height above deck	5 ft 1 in
Maximum diameter	44.75 ins
Weight equipped but unmanned	1750 lbs

Both chambers have lifting pad eyes at either end and in the middle. The of maximum working pressure of both vessels is 335 lbs psi with a safety factor of 6 times. Helicopter chamber power requirements are 24-30 volts. AC or DC (DC preferred) maximum requirement 32 amps at 28 volts.

DOWNUNDER 77

This conference, planned for over a year, was far from the smooth running function that had been expected. Probably every conference contains periods of high drama as the organisers try to salvage order from potential chaos. This one suffered a last minute change from being a cruise along the Barrier Reef to becoming settled among the hotels of Brisbane. The extremely late notice of non attendance from some featured speakers, due no doubt to the very best of reasons, resulted in amendations to the amended schedule. A lack of information sharing from the organising group to the periphery did little to assist the mobilisation of assistance from the groups nominally jointly involved, and a total lack of correspondence from the organiser of the Diving Medicine group resulted in at least one speaker being unaware that his offer of a paper had been accepted until he received a program!

Such matters are raised so that they will not recur. SPUMS members carried the brunt of the "local content" of the diving medicine section of the meeting though regrettably few non-speaking members of the Society attended. The sections on maritime archaeology, artificial reefs, underwater education and underwater photography were possibly models of organisational efficiency but the medical section of such meetings as this obviously requires much greater involvement of those involved than was the case here. Possibly any future meeting would be better designed if a workshop rather than a lecture format were to be used. Such a design would require strict planning of the keynote teams or the mixture would fail to react. Despite what has been written above there was much of value in the meeting ... but there could have been much more.

The conference was opened, for these who had not been told that there was a Saturday Seminar, on the Sunday morning. After a brief introduction by Dr Baker (of Roche) that most remarkable of divers, Dr Nic Flemming, gave a talk on the discovery of lost cities of the ancient world. The changing levels of the Mediterranean Sea relative to the land masses have submerged, and in the process preserved, the buildings of the previous inhabitants. He has been among the first to investigate such remains, a remarkable feat as readers of his article on the Israeli paraplegic divers will understand. That a paraplegic can perform such tasks illustrates the need to include motivation onto the list of fitness-for-diving factors. Unfortunately he did not address the medical section later, thanks to the restructuring of the program. However Dr Glen Egstrom, who spoke next, gave several addresses on the medical and instructional aspects of diving. He stated that for any true learning to occur, to reach what is called the "overlearning" stage where the information guides conduct without the need for conscious thought, requires 17 to 21 trials. Such thoroughness is obviously not possible in any ordinary diving instruction situation. He also noted the need for there to be similarity between the taught and the required task as illustrated by the difference between buddy breathing sitting quietly on the pool bottom as contrasted to the action performed in mid water while swimming. It seems that he believes in the need to practice "free ascent", casting scorn on mere verbal instruction. He did not state how often such practice would be required for the "overlearning" status to be reached.

Among the many factors investigated by his team at UCLA have been the effect on mobility of various suit designs, the problems associated with the dropping of weight belts by the diver in different postures, fields of vision with a mask, regulator and vest function and decrements in efficiency with cold. He is a practising diving instructor, keenly interested in safety. He has made an investigation of surf entry problems, a very important matter in California.

continued on page 49

TV GOES DIVING...IT'S A NEW WORLD!

A review such as this must eschew comments on such fictional diving as dear "007" performs, and politeness induces my pulling a veil over the gaucheries of Lloyd Bridges' 1966 effort, "Around the World Under the Sea". I for one kept wondering whether the characters realised that the pressures inside and outside a submarine differ considerably and that special gas mixtures are rarely required, even by treasure divers, when the surface is close overhead! Still it would be nice to know who made their wet suits, for the divers were able to survive submarine explosions in an area too dangerous for their submarine to enter. No, one must consider the information made available in unexpected detail by more serious programs which are nevertheless aimed primarily at the non-diving viewing public.

In the ABC Breakaway series Stewart Faichley was the reporter who tried a number of excursions into adventurous activities. In one of these he made a supervised dive at Mount Gambia. It was implied that his training was very recent, in fact for the purposes of this dive. His comments in an interview later are interesting. He reportedly said "The worst single moment of panic came at the bottom of a 32 metre dive in a subterranean pool. The first law of diving is to avoid panic but suddenly it overwhelmed me. Breathing became a wild, uneven gasping for breath. Cave-diving is the one adventure I've no desire to go back to. It's too scary. Cave-divers go into places where it is so dark they don't know up from down ... they have to feel for their air bubbles to know up". Hardly the place to take the new diver even for the sake of a TV program one might well say.

The Californian Sea Lion was featured in a Wildlife Safari program on the Sam Benito Islands off the Lower California peninsular. These animals have a very efficient dive reflex and can, apparently, dive for half an hour to 200 feet if necessary. They have the ultimate in undroppable weight belts, for they have an average of 15 lbs of stones in their stomachs, presumably deliberately swallowed. Their underwater duration was ascribed to the bradycardia and circulatory changes of the Dive Reflex plus the advantage of greater blood volume and RBC content of that blood as compared weight for weight with a man. Even so the time and depth achievements point to some additional factors. No wonder so many physiologists investigate marine animals.

Quite the most remarkable viewing was that provided by Cousteau's filming of Toussaint Recco, a red-coral seeker in the Mediterranean. This man used scuba to perform dives to 300 feet on air for up to 20 minutes. He followed his own ideas concerning decompressing, including exercising. He had one Spinal Bend to his credit at least. He was shown an untouched patch of red coral, at a depth of 330 feet, from a seat in the "saucer" underwater vehicle and decided to harvest it by his usual methods. Believing that what he did was his own choice Cousteau and his divers decided to film the event. Recco descended with the help of a heavy rock and overcharged double tanks (how else would he have enough air!) "like bombs on his back". He had a safety line, a necessity in the strong cold current if he was to be successful in hammering the coral from the rock. The Calypso divers used HeO_2 mixture and watched him work. They persuaded him to ascend at last, though he first mistakenly started to swim even deeper, due to the narcosis effect. Recco decompressed by his own ideas, the three Calypso divers by their more scientific schedule. He had resolutely said NO to the suggestion he take advantage of the underwater oxygen decompression routine started at 39 feet. Perhaps he was right, for one of the Calypso divers became unconscious and survived only because of the availability of SDC facilities. Cold, sea water inhalation, overexertion and oxygen toxicity were all suggested factors. It is doubtful if all this converted Recco to Scientific Diving to any noticeable degree.

Poor Recco died later. It was hose trouble .. with his next door neighbour at home. You see, he was safer diving. The dealer who bought the red coral for sale to jewellers summed up the morality of all concerned when he said "In all things there are Hazards, and if the diver likes to risk his life for money that is his choice."

Yes, I'm glad I do some of my diving training in front of the Telly.

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The medical sessions included Dr Carl Edmonds' description of the oxygen in water therapy for decompression sickness in remote areas. Interest in diving accidents is apparently growing in Europe, aided in some countries by a scheme for compulsory insurance. If you claim, they know of the incident! It is hoped at a later date to have a paper from Dr Coram Holmberg about the Swedish diving incidents. They have some we cannot match: lips frozen to the mouthpiece. Dr Tailleur reported that the Club Mediterranean had only had 8 bad accidents recently. All were deep dives, 6 being cord lesions. This may seem high risk diving requiring investigation.

At an open session of the CMAS Sport Medicine Committee it was apparent that there are different viewpoints as to the proper functions of that body. Some members believed that as <u>they</u> taught their children to use scuba from an early age there could be no general advice given to National Diving Organisations as to a minimal age for acceptance of pupils. There was the debatable belief, held firmly by several, that is it is physiologically safe for children to scuba dive there are no reason why they should not do so. It was also painfully apparent that there were more plans than results from past years. Optimists may expect changes to occur.

Later papers covered many aspects, including the need for a doctor examining regarding fitness-to-dive to remember the possibility of a previous disease, such as cancer, that the applicant fails to identify correctly to the doctor. Peter Bethune talked on stress effects on the diver, and Dr Peter Landsberg discussed South African diving incidents. (Interested readers can find this paper in the SA Medical Journal 1976; 50: 2155-2159). Dr Tailleur's talk on the physical requirements for users of super-fins showed that there is a competitive spirit abroad in Europe, apparently effecting even young children, that is quite unknown in Australian waters. Dr Ehm discussed the hyperventilation syndrome and Dr Gravier revealed the extent of the French firemen's diving organisation. Dr Knight talked about the Australian Diving Medicine Centres, the Diploma in Diving and Hyperbaric Medicine and other matters. Dr Egstrom, possibly te person most in demand for papers at the conference, told us about the Diving Medicine situation in the USA and the problems resulting from recent Labour Legislation.

One of the best attended meetings was that concerning the "Free Ascent" by divers. The discussion was just beginning to get lively when the Chairman called "time" and discussion was ended. This subject was surely one highly suited to a "workshop" or panel treatment. Naturally nobody has admitted to having been influenced by the opinions aired!

This is one person's opinion and apologies are offered to those not mentioned or believing themselves misunderstood. It is hoped to print Dr Bob Thomas' paper, about diving medical examinations, at a later date.

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