South pacific underwater medicine society

Journal/*Newsletter*

SOUTH PACIFIC UNDERWATER MEDICAL SOCIETY
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C O N T E N T S

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Editorial

The basic similarity of the problems facing divers wherever they are around the world is illustrated by the general applicability of the matters reported by our contributors. They write from the USA, the UK and South Africa as well as Australia and New Zealand, yet the subject matter show no such global localisation. We welcome and thank not only the authors but also the original publishers of some of these papers for their kind permission to reprint. Our thanks, therefore, to the Supervisor of Diving (US Navy), NAUI (USA), the Barologia Society (BSA), Cmdr Warner (Dept of Energy, UK) and the New Zealand Underwater Association.

The question of risk in diving is often raised, usually being evaluated in a far from impartial manner. It is therefore with special pleasure we can report on the recent investigation by a study group of the Insurance Institute of Victoria, a pleasure rather heightened by the satisfactory nature of their findings. That they have made their report public is an unusual and public spirited action for which we can be grateful. Naturally their (relatively) golden opinions of the diver's chances of failing to get a pay-out on an on-depth policy have not, so far, led to any fall in premiums! The report has useful comments concerning the significant added risks of certain types of diving and suggests that better recording of diving incidents would be rather helpful if the diving community hoped for a better acceptance by Insurers. They also noted the need for training before diving. This is an altogether admirable effort by a group of non divers, people who put their money behind their opinions and expect to come out laughing all the way to the bank.

Fitness for Diving is now being assessed in a more liberal manner by many doctors, a better awareness of the health profiles of actual safe divers now leavening the original overstrict military type evaluations of "A1 or OUT", itself in part a reaction to the previous non-military cavalier attitude to medical fitness in civilian circles. There will always be marginal cases to consider and the papers by Bangasser and Curley consider some such factors. And people being what they are, some will seek/need to "top up" their fitness by medications. The old adage that "there ain't no such thing as a free lunch" operates here, as Dr Adair explains and our cartoonist Peter Harrigan more obliquely illustrates. However the sea is never a favourable environment in which to make mistakes and morbidity and mortality are always possibilities. Avoidance of trouble is always the best policy, followed closely by acquiring an ability to recognise and remedy divergences from the optimal situation with minimal delay and distress. Such learning can only follow the observation and evaluation of the diving situations that occur, which brings us back to Incident Reporting.

The case presented by Dr Dries Jones illustrates the complex clinical situations that arise in practice, and offers an opportunity for retrospective diagnostic insights from our readers. Such reader participation will be welcomed. The cases described by Hunter et al, Duplessis, Wiles and Walker deal with decompression problems, stress being laid more on the critical factors influencing its occurrence than on the actual treatment. It is hoped that some of the bold, lucky divers will heed the messages of these papers.

Escape from the deep is a matter of intense and personal interest to submariners, who are well aware of their possible problems should their craft strike trouble. The brief article by Kerne et al introduces newcomers to diving among our readers to the continued Naval interest in safe emergency ascent from submarines.

However divers seem in general to die in situations where such emergency ascents were not the answer to their problem. The Provisional Report on the 1978 Australian diving-related deaths makes interesting reading (it is hoped!) in that the brief case reports indicate the chain of events leading to the fatal situation, the result being avoidable had the chain been interrupted. It is again apparent that the lone diver on the surface is far from being in a safe situation, especially if he is without a buoyancy aid. It is hoped that awareness of the factors present in these present in these, and other, fatalities will encourage all Instructors to stress such factors during training, and discourage “kind friends” and others from taking the untrained for a dive. This latter factor is worth frequent repeating during the instruction of all divers. It is apparent that much of the information we now have results from the investigations made by the Police to assist Coroners. Such reports are, inevitably and thankfully, not available concerning non-fatal incidents. Here only the active interest and involvement of divers themselves can produce results.

But even professional divers can come to grief and destruction, as Cmdr Warner reports. He has recently received the John Galletti Award for Diving Leadership, this being presented at the Ninth Annual International Diving Symposium (New Orleans, February 1979) on the occasion of his presenting tis paper. We are pleased to congratulate him on this award, so well deserved. The active involvement of the UK Department of Energy in the diving safety is further illustrated by the Diving Safety Memos and the present investigation into the occurrence of unconsciousness in divers.

This paper by Dr Michael Davis, reprinted by kind permission from the New Zealand Journal of Sports Medicine, was given in 1976, but remains a useful and timely reminder of the problems produced by a water environment. The author also brings our attention to the influence of hypothermia on the occurrence and treatment of decompression sickness, in his letter in the Correspondence section of this issue. Although Australian divers can become hypothermic, New Zealand ones are at greater risk of this insidious danger. The in-water treatment by oxygen of decompression sickness has, naturally, never been presented as the method of primary choice. It is a useful alternative to a long and hazardous road or air journey or a prolonged, deep air table treatment. The dangers Dr Davis outlines give point to the observation that the best treatment is not to put oneself at risk of DCS.

And finally we have the possibly mundane, but vital, matter of the Treasurer’s Report, to which must be added the reminded that SUBSCRIPTIONS ARE NOW DUE.

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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?

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AVOIDING THE BENDS

Errol Duplessis, NAUI 5307 Massachusetts

(This article was written in response to a diver of the New England Aquarium Dive Club in Boston who experienced the bends after a repeat dive, and is reprinted from NAUI News March/April 1979 by kind permission.)

Usually, whenever a sport diver gets the bends, it is due to the cardinal rules of diver safety being completely forgotten or ignored. It’s really not easy to get a “hit” when you observe the diver safety rules. But let me also stress that when you do get a case of the bends, it is usually because a multitude of rules are broken and the bends become a consequence of poor judgement.

A disturbing fact about any case of the bends is the realization that some of our sport divers are simply not prepared enough to go out and perform deep or repetitive dives. There are great risks involved in doing this kind of diving. You must know how to use the US Navy Air Diving Tables, and just as important, you must know the rules about using the tables safely.

Now let us discuss *the rules first*. These rules can be a valuable tool in planning repetitive deep dives. If you are *not* a bonafide US Navy diver, well trained in diving procedures, a *male* between 18-26 years of age, in top physical condition without an ounce of fatty tissue on your body, and very near a recompression chamber *at the dive size*, then the standard table is *not* meant for you. It’s *just a guide*. Just remember to plan your next deep dive or repetitive dives, and not really press the limits. That is the *first rule* of no-decompression diving. You could get bent five times out of every 100 dives you make, even though you qualify as a US Navy diver. The *second rule* stresses the non-decompression limits for all depth penetrations to 130-feet, the maximum depth penetration for sport diving. The *third rule* is to avoid pushing the tables so that you end your dive well within those limits prescribed by the tables.

The tables are a guide for sport divers use, and were designed on the bodies of young Naval *men* to compute the time-depth ratios. So women, keep that in mind. Not all sport divers fit the mould required of UDT Navy divers. In fact, most sport divers *never* attain this level of fitness, so who are we kidding when we talk about using the standard table? Let us play it safe by planning our dives well within those limits. If the depth is to 40 feet, use the 50 foot table to calculate time and depth. If it is a cold and arduous dive, and most diving in northern climates is cold and arduous, add another ten feet and ten minutes to depth and bottom time before consulting the tables.

In regards to repetitive diving, you should use the dive tables, a watch, and a depth gauge. You cannot calculate your surface interval time accurately without using these three instruments together. Therefore, you should own and know how to use these three instruments before you get involved in repetitive diving.

It is ludicrous to think that any Divemaster can keep an accurate account of your time and depth on any repetitive dive without your help. All the Divemaster can do is check to see that you have the right equipment for the particular dive and know how to use it, review the dive plan with you and check your actual bottom time and depth against the dive plan. The rest is up to you.

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S P U M S

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 30TH APRIL, 1979

Opening Balance 1 May 1978		
Investment Accounts - CBC Savings Bank Ltd	1645.12	
Investment Accounts - Mutual Acceptance Ltd (10.5%)	1000.00	
Cash at Bank - ANZ Banking Group Ltd	1691.43	
Cash on Hand	2.00	4338.55
Add Income		
Subscriptions	4787.68	
Bank Advice	25.00	
Interest - Mutual Acceptance Ltd	99.48	
Interest - CBC Savings Bank Ltd	260.82	
Returns from HMAS Penguin Meeting	182.00	5354.98
		9692.53
Less Expenditure		
Post	852.90	
Duplicating	104.93	
Stationery	83.96	
Newsletter	2117.50	
Travel	718.39	
Reimbursement	30.00	
Petty Cash	5.00	
Fiji Conference	183.98	
Bank Charges	69.46	
Meetings	247.35	4413.47
TOTAL FUNDS 30 April 1979		$ 5280.06

Represented By:

Investment Account - CBC Savings Bank Ltd	1905.94	
Investment Account - Mutual Acceptance Ltd (9.75%)	1000.00	
Cash at Bank - ANZ Banking Group Ltd	2372.12	
Cash on Hand	2.00	
		$ 5280.06

AUDITORS REPORT

I have examined the above statement of receipts and payments for the South Pacific Underwater Medical Society and state that the statement gives a true and fair view of the financial transactions of the Society.

ROBERT G GODDARD, ARMIT (Com) AASA

SUBSCRIPTIONS

Members pay $20:00 yearly and Associate Members $15:00. Associate membership is available to those neither medically qualified nor engaged in hyperbaric or underwater related research. Anyone with an interest in joining should write to Dr John Knight, Secretary of SPUMS, 80 Wellington Parade, East Melbourne, Victoria 3002. Membership entitles attendance at meetings and the annual Conference and receipt of the Journal/Newsletter.

Treasurer: Dr W Rehfisch, 5 Allawah Avenue, Frankston. Victoria. 3199.

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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The Selection of Underwater Diving Risks

An Insurance Institute of Victoria Report

An advanced Study Group of the Life Assurance Assessment Officers Discussion Group was formed in May 1976 following an address to them by Lt Cmdr JJ Asker, retired RAN on underwater diving hazards. The group took a long and very thorough look at the available information, in particular that relating to Australia and New Zealand, concerning the organisations of divers, training, regulations, and known mortality and morbidity. The conclusions they reached are moderate in tone and accompanied by the rider that better information is required before a firm risk rate can be calculated.

The introduction reminds readers that diving is not a new activity, pearl trading, implying diving, being recorded from China as early as 2000 BC, while the Pharaohs of Egypt got their pearls from divers in the Persian Gulf and the Red Sea. Diving apparatus was used by Andreas Peckel in 1644 to reach the wreck of the Vasa at 30 metres in Stockholm Harbour’s cold, black waters, a considerable technical feat at any time. The death rate among old time divers was high and in most parts of the world they were slaves driven below by brutal masters, even (sic!) in Europe being regarded as a poorer class of labourer of a rather disposable kind. The status of the diver did not rise till the invention of the full diving suit in England in the 1830’s, when the helmet diver became a skilled master tradesman. Even so the death and injury rate continued so high that for the next 100 years divers were considered uninsurable by insurance companies. Between 1908 and 1917 the pearling fleet operating out of Broome lost 145 divers, and an unrecorded number were left crippled, and fleets were operating from several other ports also. Today divers on oil rigs around the world work long hours at great depths but their accident rate is lower than that of most workers ashore, apparently. (Editor: this statement is debatable.)

The study group attempted to estimate the number of recreational divers in Australia, making an estimate of 60,000. They concluded that possibly 53% have received little or no instruction, relying on “a book” or “a friend”, though there are now several reputable organisations of instructors offering formal instruction to agreed standards. Consideration was given to divers under the groupings of Recreational, Abalone and Professional with recognition of the differing types of diving within these categories. The non supply of information by State Harbour Trust, Police Department (Search and Rescue) and RAN sources, which may well be the safest groups, was deplored. Their reasons were not known for non-co-operation. The six monthly medical examination of professional divers was noted, with an aside that this does not appear to be well documented from state to state, or assisted by employers.

Information concerning the Abalone divers was that the industry had rapidly decreased since 1968/69, apparently due to market factors, combined with decreased diving hours by increasingly older divers with greater concern for their personal health. The rigour of the Taxation Department was an additional supposed factor! (The number of fatalities among abalone divers may be lower than that stated in this report, however.)

In the section relating to mortality statistics and current Life Office Practice, G Whittaker FIA takes the known fatalities and estimated numbers of divers as a base to calculate crude mortality rates. The Australian figures compare reasonably with those from USA and New Zealand sources (skin and scuba combined: 0.07 to 0.3 per 1,000), being:

Breath-hold and snorkel amateur divers	0.1 per 1,000
Scuba using amateur divers	0.3 per 1,000

These risks, when loaded for office premiums, would be below normal minimal extra premiums. There is supplied a list of presently quoted “loadings” by different underwriting groups. It is noted that the judgement of individual underwriters would be called into play in considering the more risky diving conditions associated with cave, ice and night diving, or the untrained use of surface-air-supply equipment. This accurate recognition of the differing risks within the diving experience is made even clearer with the suggestion that in assessing the “risk” for recreation divers, while dive depth may be a factor, additional information, such as the diver’s training and the type of diving, also require consideration.

Australian Professional diving mortality appears to have been low but one overseas report indicates that some types of professional diving may carry a risk of 20 per mille per annum, or more. It is concluded that, judging by information made available by the PDAA, morbidity may be significant. This relates in large part to bone changes and ENT disabilities. For this reason caution is urged concerning the writing of sickness disability cover, permanent disability cover only being offerable at acceptable rates in a “pooled experience” scheme. Australian rates for professional divers are probably too high at present, but are lower than should be offered if the diver moves to work in the UK (presuming an entry into the off-shore oil industry diving). However, to quote verbatim, “until some authority or group takes on the onerous task of identifying and recording accident and sickness statistics relating to all underwater divers, it is desirable for Life Offices to avoid underwriting Total and Permanent Disablement and Double Benefit riders to Life contracts”. It is particularly noted that any Questionnaire for applicants to complete should show whether the diver life has received formal underwater training and is aware of the importance of diving safety, as well as type of diving, depth, locality, extent, etc. as presently required.

The report concludes with a useful section on diving safety, present legislation, log books, some case histories, and the PDAA diving injury health survey summary. This is a document that should be studied by anyone interested in safer diving (and cheaper Insurance cover!). It provides a unique view of diving risks as they appear through the unemotional eyes of those skilled in backing their opinions in the market place. A repeated and very significant comment concerns the need these persons see for more investigation of the true occurrence of diving-related mortality and morbidity before better rates can be negotiated. So don’t say “nobody don’t told me!”

(Copies of this Report can be obtained direct from the Insurances Institute of Victoria, 410 Collins Street, Melbourne, at a nominal price yet to be determined.)

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Safety will be increased if moves are made towards adaptation to the use of RCV’s or stand-off techniques - particularly for high pressure applications. More liaison between manufacturers and divers would be an advantage and should be encouraged.

PSYCHOLOGICAL STRESS IN DIVING

Lt Michael D Curley, MSc USC
Naval Medical Research Institute

(Reprinted by kind Permission of the Supervisor of Diving, USN, from FACEPLATE Winter 1978)

US Navy divers are often called upon to perform strenuous work under difficult diving conditions to ensure that mission objectives are met. Each diver must therefore be both physically and mentally capable of responding to emergencies quickly and correctly. The often-heard term "mental toughness" refers to the ability of the Navy diver to cope successfully with circumstances that, if left unchecked, can lead to a psychological stress state.

The formation and pattern of psychological stress among Navy divers is under investigation at the Naval Medical Research Institute, Bethesda, Maryland. The effects of water temperature, exercise, breathing gas, pressure, and the like on diver performance have been the subject of extensive research by diving physiologists, but it is only within the last decade that the psychological stress include apprehension, fear, panic, and anxiety.

Stress traditionally has been defined as *a state of bodily upset or imbalance*.[4] It is a disturbance of the body's normal state of functioning and can be measured by various psychological and physiological tests. Familiar examples of stimuli that can trigger a stress state are the appearance of a great white shark or the sudden development of a 5-knot current. Moreover, even the *thought* of being approached by a hungry great white while in the water cab be stressful to the individual. It should be pointed out, however, that stress is not always a negative state. Under certain conditions stress may relieve boredom and serve as a mobilizing force for future strain. An example of the latter would be the physiological state of test pilot Scott Crossfield, whose heart rate peaked at 185 beats per minute just before take-off in the X-15 experimental plane.[1]

Psychological stress results from varying conditions that disrupt or endanger well established values: such conditions may or may not affect physiological survival and well being. Thus, a cognitive component is added to the traditional definition of stress. The psychological term "threat" seems ideally suited to express the condition of the diver when he is confronted with a stimulus that he perceives as endangering important values and goals.[6] Threat implies a cognitive interpretation by the diver about the harmful significance of the situation (eg. deciding in the midst of a 150-foot dive that his reasoning is becoming affected by nitrogen narcosis) as compared to direct tissue assault (stress/shock induced by a shark bite).

Psychological threat to the diver can take many forms, including a perceived attack on the diver's status, orientation, comfort, values, and standards. His threat may lead to the development of a diver stress state that is a debilitating as that arising from direct tissue assault.

An example of psychological threat familiar to many Navy divers occurs during the harassment portion of Navy scuba training. Although this harassment takes place in shallow depths with minimal physical discomfort. It is the formation of a psychological stress state which makes this phase of training one of the most difficult for many diver candidates. For, not only must the diver be physically capable of handling emergencies, but he must also be able to cope successfully with the psychological threat of losing his air, equipment, and dive buddy, as well as the apprehension he feels at the prospect of drowning.

Most Navy divers are intuitively aware of individual differences in reactions to stressful diving situations. Why do some divers remain calm and collected in the presence of dangerous marine life, yet others display extreme agitation? Psychologists believe that the behaviour displayed by a diver is determined by that diver's previous learning history, biological temperament, and 'he particular environmental setting in which the diver finds himself. In other words, there is an interaction of learned, genetic and cultural factors.[1] Stress must be defined in terms of an interaction between the diver and the situation — not either alone. Any stimulus may be stressful in a given situation for a particular individual. And, except for extreme and life-threatening situations, no one stimulus is stressful to all divers exposed to it. To alter a popular phrase, "Stress is in the eye of the perceiver".

Now that we have defined psychological structure, let us turn to the problem of recognizing it in the diver. Behavioural indicators take many forms. Often the diver will verbally indicate his stress prior to the dive, or just before entering the water. A diver may complain of various physical ailments such as headache, nausea, insomnia, or gastrointestinal distress. Other divers or tenders may notice an increased hostility and/or irritability in the affected diver. "Gallows humour" may be present, a phrase referring to the practice of joking about the possibility of severe injury or death in the water.[2] Anxious divers may verbalize strong concern over relatively routine matters or problems easily corrected.[1]

Physically, manifestations of diver stress may include profuse perspiration, pupil dilation, and tremor (shakes). The psychologically stressed diver may fumble inefficiently with his gear and seem "all thumbs". Changes in mood are often present: the normally out-going, life-of-the-party diver suddenly maybe withdrawn and quiet. Similar changes may be apparent in normally quiet individuals who become extremely active. Once in the water, a diver who is experiencing stress may display jerky, abortive movements, as well as frequent glancing a t the surface, equipment adjustments, and communication checks. Increases in air consumption and heart rate may also occur.[5]

Divers who cope successfully with psychological stress generally display most of the following characteristics.[3] They possess an accurate perspective of the risks and benefits attendant to diving and actively seek out the latest information regarding diver equipment, training, and safety. These divers are able to express freely both positive and negative feelings and can tolerate frustration. When faced with a difficult problem, these men break down the problem into manageable bits and work through them one bit at a time; they accept assistance from others and show flexibility and willingness to change. Successful divers are in tune with their physical state, can pace themselves and are able to recognize the onset of fatigue and the accompanying tendencies toward disorganization. Finally, divers who can cope with psychological stress have a basic trust in themselves and possess a basic optimism about life. Valid trust in one's ability as a diver to cope with stress is arrived at through hard work and intensive preparation. Successful experience in coping with stressors during Navy diving training is a good insurance policy.

There are several "direct action" tendencies that may be utilized in coping with stress.[6] A diver may take actions aimed at strengthening his resources against harm, such as proper physical conditioning, advanced training, and preventative equipment maintenance. Some divers may become aggressive and attack the source of stress. Aggression may be verbal or physical, subtle or obvious. Many Navy divers are known for their "can do" attitude in tackling difficult situations. Another manner of coping with psychological stress is to prevent contact with or avoid the agent of harm. This coping behaviour may take the form of cognitive action (ie. not thinking about something) or physically avoiding the area (eg. not diving in an area where sharks are present). Joking may also be used as an avoidance device. Lastly, a diver may resort to inaction - doing nothing at all - when stressed. For example, a diver may be totally resigned that there are no direct ways of preventing harm. Reports from near-drowning victims indicate that there is no panic when all exits are closed.

Current Navy research into psychological diving stress involves the psychological and physiological testing of men involved in extended saturation dives. A better understanding of the nature of psychological diving stress will assist Navy divers and their supervisors in safely carrying out the Navy diving mission.

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Update on NSW Oyster Health

Readers will remember the recent report from the Public Health Service in NSW, reference the purity testing of Oysters, and may be curious concerning the progress of this experimental reintroduction of the post of Food Tester. According to a recent report (The Daily Telegraph, 11 July 1979) one can feel some sympathy for these gallant volunteers who did eat oysters in the Public interest, for they are falling sick and not being given the credit for their sacrifice. Perhaps the Health Department feels that the trial was not set up correctly, with placebo oysters for a random group of samplers. Be that as it may, the sale of the oysters has been allowed despite attacks of violent illness among the tasters. This was defended on the grounds that there was no evidence that the illness was due to the oysters that had been consumed. "We felt it was reasonable to let the oysters through", a spokesman said. The tasters,

continued on page 18.

<u>Diving in the North Sea during 1978: Situation Report</u>.

Commander SA Warner, MBE DSC
Chief Inspector of Diving, Dept of Energy UK

(This paper was originally presented at the Annual meeting of the United States Association of Diving Contractors in New Orleans)

Early in the New Year a diving operation was conducted in a Norwegian fiord to demonstrate the ability of divers to weld underwater in depths in excess of 1000 feet. Unfortunately during preparation for the welding demonstration a diver lost his life at depth. This accident was investigated by the Norwegian Diving Inspectorate and their investigation showed that the welding techniques were in no way involved.

After the investigation the Norwegian Diving Inspectorate gave permission for the demonstration to continue. However this permission was retracted but permission was given to recover all the heavy equipment from the sea bed using divers. This was done successfully.

In the interest of advancing diving knowledge and techniques the company concerned were keen to continue the demonstration and requested permission to conduct diving operations within UK territorial waters. They showed that scientific and work-up trials had already been conducted to the depth of water in which they intended to operate and that, on other diving operations, they had already logged 14,400 man hours in saturation at the 1000 foot depth range in support of open sea constructions. Three hundred and thirty hours of this time were employed with divers performing various tasks actually in the water. In my opinion this had already verified the procedures and the ability of the divers to work safely at these depths.

Following discussions with the company concerned, and the various UK government departments, it was agreed that there was no sound reason why the demonstration should not be allowed to continue in UK waters.

It was considered that a successful demonstration of the ability of divers to produce a pipeline weld in depths of 1000 feet would be a significant step forward in underwater engineering involved with the oil industry and would be of considerable importance when it comes to the development of oil and gas discoveries in deeper waters around the world and, as you all know, this demonstration was successful.

At the back of my mind was the occasion, many years ago, when a diver lost his life at the very start of a major deep diving experiment and because of this the whole experiment was cancelled. In my opinion this delayed the progress of diving and eventual improvement in diving safety for many years.

Minor incidents, near misses and dangerous occurrences continued to occur in the UK sector in 1978 at a level not unlike that of previous years but, we were all extremely pleased to acknowledge, in October of last year that there had been a complete year in the UK sector without a fatality. If only to prove one must not be complaisant, at the end of November, there was an incident in which two divers lost their lives. This particular tragedy occurred during the application of a comparatively new technique of diving from a dynamically positioned vessel.

The employment of these vessels on pipeline work, or work in the close proximity of an installation where the seabed is covered by the various accoutrements of the trade of offshore oil exploitation is extremely attractive. In many cases the employment of an anchor mooring system is either undesirable or impossible.

However, it is clear that diving operations from a dynamically positioned vessel must be carried out within the safety envelope of the diving system, the vessel, dynamic position system and the prevailing and anticipated weather and sea conditions.

Both the Norwegian Diving Inspectorate and the UK Inspectorate have been trying to anticipate the problems involved with diving from these vessels and only late last year the UK issued a guidance note drawing attention to the problems of a single acoustic system. It is a fact that we are all still on the learning curve with this type of operation.

Our efforts in investigating and assessing the safety parameters of this particular technique have naturally been increased by the unfortunate tragic happenings recently. The UK has now initiated a research project to perform a risk analysis study of diving from dynamically positioned vessels. The object of this analysis being to: establish parameters for the design and operation. The study will take into account and advise on requirements for redundancy in thrusters and screws, propulsion machinery, power supplies, sensor systems and individual sensors and computer hardware. It will also consider the design requirements for computer software and will make recommendations upon these and on operating procedures to be adopted in relation to such facts as operating in the vicinity of fixed structures, both surface and subsea, the proximity of anchor cables and wires, changing the ship’s position both laterally and in asmyth while diving operations are being performed and the limiting weather conditions. In addition it will study and make recommendations concerning on board and diver communication systems.

The results of this project will be published as soon as they are available.

The continuous process of analysing the facts and figures gathered from accident reports and investigations is showing little change and human error still continues to head the list at about 50%. However, I must stress that when I quote “human error” I do not mean just the “diver’s error”. Human error covers every aspect from the human involvement in the manufacture of equipment right through the whole process of diving to the actual man in the sea. We have started a punch card recording system in the UK as a means of collecting as much information as possible on accidents. One must however remember that the end results are only as good as the information that is put into it. Eventually it is hoped to include all this information in a computer.

One particularly worrying aspect in the North Sea in 1978 was the fact that 3 diving bells were dropped for various reasons. This once again generates the almost continual debate on “to have or not to have slippable weights”. It is a fact that more divers have lost their lives through accidental slipping of bell weights than those saved. Because of this some companies have fitted additional external keep pins or chains to bell weights which require the diver, in the event of an emergency, to leave the bell and to remove the external safety device before returning and closing the bottom door or doors before actually slipping the weights.

UK legislation requires a method of recovery in the event of a main wire break and providing there is at least one additional method of bell recovery (for example, recovery by umbilical or guide weight wires) the external pinning of slip weights is acceptable. However, diving companies must take into account the design of the bell system. For bells that sit off the bottom by the by the application of an under slung weight or those that stand on, but clear of the bottom, by the use of legs or some such device under some circumstances it is acceptable to have external safety devices. Where the straight forward bell suspension technique is used it must be appreciated that if the bell is dropped on the bottom the divers may well be unable to leave.

It would seem sensible to ensure that where slippable bell weights are employed as a means of emergency surfacing, the slipping procedure should consist of two positive actions neither of which can be carried out accidentally. It is also desirable to have an interlock between the slipping device and the bottom door to prevent slipping with the bottom door open.

This automatically leads to another practice that appears to be creeping in with some companies, and that is the practice of removing the bell bottom door when operating in saturation diving. There are many attractions for doing this and, generally speaking, it is acceptable when the storage depths of the divers is seabed depth.

However there is increasing activity at the inspection and maintenance role, much of which is carried out at intermediate depths and divers are being saturated at these depths. A dropped bell under these conditions with only an internal pressure sealed door could be disastrous. Prevention must surely be the first line of defence.

All of these problems suggest that a new look at bell designs may be desirable.

During my talk last year I told you that it was the intention of the Government to introduce a new unified set of diving regulations therefore tidying up the present situation which included 4 different sets of statutory instruments.

The proposed regulations will apply to all diving operations whilst at work, both offshore and inshore, including those carried out by employees of the Crown but not, and I repeat not, to sport or amateur diving.

The new proposals include the legislation which the offshore industry in the United Kingdom have accepted and learnt to live with.

Within the proposals there are certain points which tighten up the activities of the diving “inshore” but, in the long term, it is hoped it will not only improve diving safety but introduce a career structure for people involved in the industry.

Some difficulties are being encountered in trying to cater for “scientific diving”. One of the biggest problems has been to define “scientific diving”.

<u>Long term future investigations</u>

The Chief Scientist of the Department of Energy, Sir Herman Bondi, has set up an Advisory Group on the technological development necessary for the progressive replacement of man under water in the long term future. The Advisory Group has been set up to advise on the research and development support necessary to assist the development technology required for underwater engineering to move towards the progressive replacement of man underwater by remotely controlled systems.

I believe that we all support the policy that if a task can be completed successfully and economically underwater without subjecting man to pressure it should be done that way. I would agree that this should apply, in particular, to very deep water. I do not know where the economically break point is but the present state of the art in deep diving and with the introduction of helium conservation systems I would estimate that manned diver intervention underwater will continue to be economically viable down to depths of 1000 feet for the foreseeable future.

History has also shown that “non diver techniques” have provided an excellent source of diver employment.

Currently in the North Sea manned free swinging submersibles, some with diver lock out facilities are being used. The capability of this class of submersible has improved a great deal in a relatively short time with advances in battery technology, control system, underwater navigation, lighting and viewing systems, and vehicle design. However, the happenings in 1978 suggest that the market was over supplied.

Submersible operations in 1978 in the North Sea were not without their incidents. Early in the year a two manned observation submersible became fouled on the sea bed but was safely recovered after several hours. Early on Christmas Day I was informed that a two man non lock out submersible was fouled in about 400 feet of water but, fortunately the message came through at 3 o’clock in the afternoon that the vehicle was safely recovered.

There was very little activity by the one man one atmosphere type submersibles during 1978 but I anticipate that this type of activity will increase considerably in the future.

Remotely controlled vehicles are being used in a limited way, mainly in the task of inspection and these consist of:

(i) tethered and untethered free swimming vehicles;
(ii) tethered bottom crawling vehicles; and
(iii) towed vehicles.

Some have demonstrated a capability to perform inspection, survey, and some recovery tasks. However, general acceptance of the RCV’s as such have not been fully achieved in the oil industry.

Diving Safety Memorandums

Gentlemen, it would be very wrong of me to conclude a diving safety survey of operations in the North Sea without mentioning safety memorandums that have had to be issued.

Individual diver carried decompression meters are extremely attractive for use by divers carrying out inspection and maintenance of structures. However, we had to draw attention to the fact that some meters available on the market are not necessarily safe for this particular diving application.

In February of last year it became obvious that there had been too many serious “near misses” as a direct result of using electrically heated undersuits. We had to say that these suits were not to be used in the British Sector unless the control circuit is so arranged that adequate electrical protection is provided to minimise the danger from the failure of the insulation and from over current.

Some concern has been expressed on the subject of “diagnosis of decompression sickness”. We have drawn attention to that excellent section of the US Navy Diving Manual headed “Patient Examination”.

The fact that the sea is sometimes very rough and that it is necessary to secure equipment in a seamanlike manner also had to be pointed out.

The fact that this has been necessary may well reflect on the standard of diving supervisors and this I intend to look into.

Discussions on the desirability of having a hyperbaric lifeboat for use in the event of ship or installation evacuation continues. We still believe in the UK that, with the state of the art today, the application of “prevention” backed up by a “flyaway” capability and a ship to ship “lift off” capability fills the requirement of providing “every reasonable practicable precaution”.

During 1978 we also had to draw the attention of diving companies and equipment manufacturers to various defects in equipment. In every case there was a rapid response from the companies responsible.

I also found it necessary to draw attention to the activities of some “diving consultants”

I would now like to touch very briefly on the research projects which we are supporting.

The investigation of unconscious episodes in divers and management of diving accidents continues.

Investigations on anaesthesia at high pressure is progressing well and successful trials have been carried out under controlled conditions at equivalent depths of 1000 feet. (This work is being done by Dr CR Dundas of Aberdeen University).

The investigation into safe thermal conditions of divers is also continuing and I hope that by this time next year one would have some very definite results to report. (This particular project is being carried out by Dr V Flook also of Aberdeen University).

The investigation into diver fatigue at the work site has been broken down into, first of all, the technique for monitoring the diver. It is certainly interesting to note that, with the information that we have today, there appears to be little medical reason for restricting divers’ activities in saturation, length of time in saturation, and number of saturation dives per year.

Carbon dioxide retention in divers and helium breather warning devices are being investigated by the Admiralty Marine Technology Establishment. Dr M Winsborough of the same establishment is responsible for producing tables for oxygen/ nitrogen saturation.

Investigations into electrical safety underwater continues and I hope that in the very near future we shall know the areas in which we have little or no knowledge and will therefore know where to direct future research.

As I told you earlier a research project has been generated to cover the problems with operating divers from dynamically positioned vessels.

Finally investigations still continue into the long term environmental effects of diving. This is going extremely well and certainly, at this stage, there is no reason to anticipate serious future problems.

The results of all these projects will be published when the projects are completed and, if any particular point of safety arises during the research period this will be published at once.

As you know from some of my statements in previous years I sincerely believe that we should aim for harmonisation of all diving safety regulations in the offshore industry. I still believe this but I think that a word of warning is perhaps necessary. My idea of harmonisation is not the production of detailed legislation. Too much detail can only lead to a restriction in progress and the delay in the introduction of new techniques.

I shall certainly be taking a keener interest in the ILO and IMCO committees in the future.

Finally I can tell you that the English translation of the Norwegian Regulations is now available.

EYE TESTS FOR PENGUINS

Penguins are well known for their ability to “fly” underwater and catch fish, the mainstay of their diet. Because of their expertise at such aquatic manoeuvres, it has been thought that the penguin eye was optically adapted for underwater vision, suggesting that their vision in air must be greatly near-sighted.

Findings by Dr Jacob G Sivak of the School of Optometry, University of Waterloo, Ontario, Canada, however, appears to refute this theory. Impressed by the ability of some penguin species to recognise individual birds on land and to travel great distances over featureless ice using celestial navigation, Sivak decided to test the aerial and aquatic vision of penguins. Blackfoot penguins were given a series of intensive optical tests, the results of which showed that the birds’ eyes were well adapted for aerial, rather than underwater, vision. Sivak also noted, however, that the penguin eye has a very flat cornea, which could function similarly to a skin diver’s mask, reducing the far sightedness that is usually introduced by submerging an eye designed for aerial vision. Studies of additional penguin species (rockhopper, gentoo, king and Adelie) have indicated a similar pattern.

(Reprinted by kind permission of The International Oceanographic Foundation’s SEA SECRETS volume 22, no 6, 1978).

Update on NSW Oyster Health continued from page 12.

who are drawn from the ranks of Sydney’s public servants and are all volunteers, are covered by Government sickness and workers compensation benefits. The suspect batches seem to have been uncontaminated when assessed by chemical tests. The article concludes with the comment that despite the well-publicised support for the oyster from members of the State Cabinet, including Health Minister Kevin Stewart, the industry has only just managed to regain the public’s confidence. It will be a great relief to many oyster eaters to know that however ill they may get, the chemical tests were satisfactory!

No. 6: DYSBARIC OSTEONECROSIS

As a result of recent publicity in the UK about divers and dysbaric osteonecrosis the Diving Medical Advisory Committee of the Association of Offshore Diving Contractors obtained up to date information from the Medical Research Council Decompression Sickness Central Registry in Newcastle-upon-Tyne. This registry, which has been collecting bone and joint X-rays of divers since 1968, now obtains, and comments on all the X-rays taken of the bones of professional divers having medical examinations in the United Kingdom. In 1977, 2,174 X-rays were dealt with by the registry. In all, records exist for 4,030 divers, this representing the total since the founding of the registry.

Before commenting on the figures obtained as a result of its request, DMAC considers it relevant to make some general observations on the problems of interpreting the available statistics. It is, for example, important to realise that the figures should be seen as representing a crude measure of accessing the overall prevalence.

Whilst the information held in Newcastle can be computed to relate incidence to age, diving experience and types of diving carried out, such an exercise depends on several years of accumulated information before realistic interpretation becomes possible. It is therefore probably too early to present a detailed breakdown of the information in such a form.

What is clear from the figures is that dysbaric osteonecrosis in all its forms is lesions which have no long-term significance to a diver’s health and well-being. There are differences of view regarding the possible limiting effects of “shaft” lesions. Some doctors take the view that a diver with these lesions should be limited in his diving activities. One possible interpretation of the data held in Newcastle is that the presence of a shaft lesion does not indicate that a diver is more likely to suffer from a joint lesion subsequently than a diver who has not got a shaft lesion.

There is general agreement that divers with “joint” lesions should stop diving. These lesions may or may not progress to produce severe damage in joints but continued diving probably increases the risk of such an outcome. As it is, divers are now routinely picked up with the earliest X-ray signs of “joint” lesions and who suffer in any way from dysbaric osteonecrosis.

The figures from the Newcastle Registry, as of December 1978, are as follows:

Total number of divers screened:	4030	100%
Normal X-rays and minor abnormalities unrelated to diving	3973	94.1%
Suspected “shaft” lesions (possible early signs)	61	1.5%
Definite “shaft” lesions	95	2.4%
Suspected “joint” lesions	42	1.0%
Definite “joint” lesions but with joint surfaces intact	32	0.8%
Definite “joint” lesions with damaged joint surfaces	4	0.1%
Joint damage with disability	2	0.05%
Joint damage leading to surgery	1	0.25%

DMAC considers these figures must be regarded as reassuring. In particular, only three out of 4030 divers had definite and disabling joint damage and there is no reason to suspect a dramatic change in this figure in the future.

Further, the incidence of dysbaric osteonecrosis in the United States Navy and the Royal Navy is fully in accord with the above figures and confirms the low risk to divers.

In conclusion, DMAC believes that the publicity could have given rise to misunderstanding. What is clear is that the area of major concern is over that of the diver with "shaft" lesions suffering a loss of earnings following a restriction to air-diving only. This problem is not new and may be resolved favourably from data being collected at Newcastle.

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No. 7: <u>SHIP DYNAMIC POSITIONING SYSTEM</u>

A further report of a serious "near miss" situation where two divers in a bell were put at risk through a failure in a DP system emphasises the need for caution in the employment of the techniques of operating diving from a DP vessel.

Further incidents may necessitate the restriction in the use of this technique or possibly a total ban.

Diving Safety Memo No. 19 1978 refers.

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No. 8: <u>DIVER HEATING</u>

Experience shows the importance of always maintaining the diver in safe thermal balance and, in particular, in an oxygen/helium pressurised environment. Almost certainly, many of the unexplained incidents in the past have been in some way due to the effects of cold.

Research is continuing into the need and the application required to maintain divers in safe thermal balance.

Hot water systems are used with some considerable measure of success on a majority of deep diving spreads in the North Sea. Many of the systems use a technique of pumping hot water straight from the heating unit to the diver. This technique has certain limitations and can, accidentally, produce hot or cold water "slugs" to the diver. In addition, the failure of the heating unit can result in complete loss of heating for the diver.

Research shows that with a loss of artificial body heat under oxygen/helium pressure conditions that there is a rapid reduction in the skin temperature. This is usually recognizable to the diver and he should be instructed to return immediately to the diving bell under such circumstances. Enthusiasm to complete a task by continuing work under these conditions can put the diver at risk.

In order to increase diver safety where the hot water technique is used, consideration should be given to providing a main and secondary hot water supply, and incorporating a "hot water reservoir" in the diver heating system.

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No. 9: UNDERWATER JETTING PRACTICE

Safety Considerations

The use of water jets for underwater cleaning is inherently a dangerous operation. The situation is made worse because of the effect of the associated turbulence and noise on the vision and communication of the diver. Future increase in operating pressures or addition of abrasives will only marginally increase the risk to the diver. Adequate training and appreciation of the hazards are therefore very necessary. In the absence of alternative procedures the Department’s Diving Inspector and the Health and Safety Executive accept the use of water jets in the offshore environment.

Operational Hazards

Accidents could occur in the splash zone where it is possible to get the retrojet in air and the main jet in water. An automatic cut-off device for such an eventuality might be worthwhile.

Jetting guns are activated by a trigger mechanism. It is reported that holding the trigger rapidly causes hand fatigue so there is a temptation to “modify” the system to relieve this. It is suggested that the activating trigger should be redesigned - for example, a two-pressure device; positive action through the first action and light pressure action to maintain the flow.

One problem very specific to safety relates to the use of trigger-operated valves of the water guns. Most of these are of the pressure balance type and even with excessive trigger pressures (which are difficult to use for extended periods), have a tendency to stick in the ‘on’ position. With abrasives being in the locality (even though nominally not being passed through the valve) the possibility of valve sticking is enhanced. Valve designs that are less prone to this particular problem need to be explored.

Design Suggestions

For certain straight forward cleaning applications, the incorporation of a shoulder butt should be considered to ensure that the retrojet is directed over the shoulder. On certain guns, the retrojet shroud can unscrew in operation; it should be positively pinned.

With modified nozzles, etc it is possible that the filter to the header and between header tank and pump (where fitted) could pass solid material capable of blocking either the main or retro-nozzle. The size of the filter mesh should be specified and a shut-off or dump value should be incorporated against such an emergency.

Much useful power is lost in present designs; perhaps 25% in transmission and 50% off the remainder in the retrojet. The retrojet could in principle be replaced by a low power shrouded propeller or venturi thus increasing the available power and eliminating one inherent danger of the device. Such a replacement would, however, need an inbuilt control system to establish and maintain the balance of forces.

General Safety Considerations Regarding Future Developments

The carefully controlled use of higher pressures and abrasives will only marginally increase the hazard of underwater jetting. The problems of rigidity and the risk of blow-out due to higher pressure feed hoses can be reduced by the use of a pressure intensifier at the gun end.

continued on page 9

<u>Discussion of a case</u>

Dr Dries Jones
(Senior Medical Officer, SAN Medical Centre, Simonstown, RSA)

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Diver GJE, age 19, performed a controlled ascent during his training in September 1975. This followed 18 minutes at 21.3 metres (70 feet). Within minutes of surfacing he developed an acute headache, pain in the right side of his chest, partial blindness, and became unconscious. He was immediately put onto 100% oxygen and transported to the SAN Diving School. On arrival, within 10 minutes, he was noted to be disorientated and to have a severe headache.

Therapeutic recompression was initiated according to Table 62 (Oxygen at 18 metres. Total time 4 hours 45 minutes). Disorientation, chest pain and blindness had disappeared after 5 minutes at 18 metres. Pulse 60/min, BP 120/80, ENT:NAD. Fundoscopy normal. Respirator system: NAD. CNS-absent abdominal reflexes, hyper activity in patella reflexes and hypaesthesia of the lower limbs. Severe headache persisted and vomiting started after 30 minutes.

The headache and vomiting persisted even after 3.5 hours. A blood-sugar evaluation revealed blood glucose of less than 40 mgm% so 20cc of a 50% Dextrose solution was given intravenously, with immediate relief of both headache and vomiting. After 4 hours 45 minutes he was symptom free. Mild weakness was felt in the legs but could not be demonstrated. A full clinical examination revealed no abnormality. X-ray of the chest was normal. Diagnosis: pulmonary barotrauma, with arterial air embolism either aggravated or simulated by hypoglycaemia.

Four hours later the patient suddenly collapsed with acute headache, becoming unconscious with flaccid paralysis of the lower extremities. He was placed onto oxygen and taken down to 18 metres. Roused with difficulty, but then disorientated. Still flaccid paralysis of lower legs with complete sensory fall-out below the waist and absent abdominal reflexes. Level of consciousness improved and he could move his legs with difficulty after 1 hour. On this occasion intravenous dextrose did not improve the patient’s condition.

On advice from the UK the patient was taken down to a depth of 50 metres for treatment according to Table 55, after 2 and a half hours at 18 metres breathing oxygen intermittently. On arrival at 55 metres again, complete paralysis of legs with pains in legs and worsening headache. Medical treatment was started after half an hour at 50 metres:

Dextran 40 ivi – Heparin 5,000 U subcutaneously
Dexamethazome 100 mgm 8 hourly
Furasimide 20 mgm ivi
Maxolon 2 cc statim.
After 2 hours the patient could stand with difficulty.
After 3 and a half hours symptoms of urine retention, but due to exposure by all doctors, a catheter could only be introduced 2 hours later (at 18 metres).

After 2 hours at 18 metres the patient developed an acute pain in the right side of his chest, with paralysis of both legs. The breathing mixture was then changed to 100% for 20 minutes and air for 5 minutes for the third hour and again for the sixth and last hour of this stop. The symptoms cleared whilst on the first 20 minutes of oxygen. The same regime was followed the hour before and after depth changes from 18-15, 15-12 and 12-9 metres. From 9-6 metres the depth change was made on oxygen for 1 hour. At the 6 and 3 metre stops, air and oxygen for 1 hour stops alternately without shortening decompression (as in Table 54) has been used due to the seriousness of the symptoms.

Seeing that the last symptoms and/or signs were found 24 hours before surfacing, it came as quite a shock when the patient had difficulty in walking due to weakness of hip muscles, and to some extent also weakness in the left leg. He also had some sensory fallout in the right leg in the segmental distribution of the L4-S5. However a full neurological examination after 3 months revealed no neurological residuae and the diver was declared fit to dive again.

Discussion

1. Diagnosis
2. Therapeutic decompression: air or oxygen
3. Medical Treatment
4. Advice re diving fitness
5. Prevention: a) training
   b) Diagnosis of tendency

1. Diagnosis

The maximum no-decompression dive time at 70 feet (21.3 metres) on US air tables is 50 minutes, and on RN air tables 40 minutes. The dive time in this case was 18 minutes. In questioning the diver after the incident it seemed that he started following a small air bubble by holding his thumb underneath it. As the bubble expanded on its ascent he admitted that he had difficulty in keeping up with it. It can only be surmised that he had closed his glottis for the crucial time to achieve a pressure of 90/150mm Hg=1, 18-1,97 msw to cause the over-distension to produce lung damage. There is also the possibility that a mucus plug, etc could have caused obstruction of one of the smaller bronchi, this causing the injury, ie. rupture of alveoli with air bubbles being sucked into the pulmonary veins and so being distributed to the systemic circulation, causing arterial air embolism. The diagnosis this seems to be pulmonary barotrauma with arterial air embolism causing cerebral and spinal cord emboli.

According to Spencer (1976) any excess inert gas stressed the nucleation sites where bubbles are formed. One can thus assume that the introduction of air from the pulmonary bed may have caused these nucleation sites to grow and rupture causing secondary bubbles, depending on how critically they were stressed before the time.

The concept of bubble/blood interface effects causing protein denaturation, formation of lipid emboli, red-blood cell sludging in micro-vessels, platelet aggregation and activation of both coagulation and fibrinic systems has become widely accepted. So the initial release of small quantities of gas from a few over-distended alveoli may be the trigger for severe and life-threatening symptoms developing.

2. Therapeutic Decompression Air or Oxygen

The treatment of pulmonary barotrauma with air embolism has empirically been on compressed air at 50 metres. The argument is: at 50 metres (6 ATA) there will be a reduction in bubble diameter as volume is reduced to one sixth, and this will allow the bubble to pass through the capillary to the lungs, or to a point lower down, where it would cause few symptoms. This argument is based on spherical bubbles. According to Buckles (1968) the intravenous bubbles have a length-to-diameter ratio varying from 1-1 to 1-30. Bubble diameter reduction seems to be beneficial only under certain circumstances. For this possibly beneficial effect it was proposed by Walder (1967) and the Bureau of Medicine and Surgery Instruction (1976) to take divers with low inert gas levels down to 50 metres for a short time and then bring them back to 18 metres to complete one of the therapeutic oxygen schedules.

The beneficial effects of oxygen at 3 ATA as compared to air at 6 ATA are:

a. To keep the partial pressure of nitrogen as low as possible, to minimise any contribution which absorption of nitrogen during the recompression itself may make to the recurrence of the lesion.

b. Studies by Wyman and Van Liew indicated that the lifetime of a bubble should not vary appreciably with pressures in excess of 3 ATA.

c. The bubble reduction of an oxygen breathing patient is 4-5 times greater than with air breathing at 3 ATA.

d. The gas tension gradient from bubble to tissue is maintained optimally throughout recompression, therefore unlikely to permit bubble growth with re-occurrence of symptoms.

e. Oxygen breathing at increased pressure is specific treatment for adequate oxygenation of hypoxic tissue, preventing further oedema with an increased hypoxic area.

f. It has further been shown that oxygen at 3 ATA is a specific treatment for cerebral oedema (Thiede and Mahley 1976).

One incident in which the use of oxygen tables seems to be contra-indicated is after long deep air dives where the tissue pp of N_2 would be such that a pressure of 3 ATA would not arrest bubble growth.

The recurrence of symptoms in this case could have been attributed to:

1. The presence of blood/gas interface action with haemoconcentration, red cell aggregation, increased clotting tendencies with development of disseminated intravascular coagulation.

2. Inadequate time under pressure

    a. Workman himself advocated the lengthening of the Table 62 by adding an extra 5 minutes air and 20 minutes on oxygen at 18 metres, an extra 15 minutes air, 60 minutes oxygen at the 9 metre stop, or to include both, in slow responding patients.
    b. Perhaps if Table 54 or 55 had been followed, there might have been no lapse.

3. Medical Treatment

This should always be supportive to therapeutic decompression and should be used alone only when no recompression facilities are available. There is, however, more and more evidence that in all cases of acute decompression sickness concurrent medical treatment is mandatory (Elliot 1974 COMEX Medical Handbook; Boorman 1968 et al). Medication as mentioned has been advocated for many years not only for decompression accidents but also as treatment of cerebral oedema. Heparin seems to be more effective in smaller doses, ie. 2000 U given as a bolus intravenously, 6 hourly. The dose of dexamethazone seems to have been unnecessarily high: after an initial dose of 100 mg, 8 mg 8 hourly seems to be sufficient. Steroids used in conjunction with hyperbaric oxygen have been reported to increase the likelihood of CNS toxicity. The use of Diazepam prior to the start of decompression should overcome this problem. Glucose 50%, apart from the value of its use in hypoglycaemia, has a direct effect in the reduction of intracranial pressure. Unfortunately a rebound phenomenon occurs due to its rapid metabolism, this causing hypo-osmolarity with subsequent increase in brain water. When used for hypoglycaemia it should be given in saline. The question arises whether our use of 50% Dextrose had well given the initial relief of symptoms by its effect on the brain oedema, but caused a relapse through causing brain oedema afterwards.

4. Advice regarding diving fitness after a decompression incident.

   a. It has been shown by Elliot and other researchers that changes in the blood composition take up to 10 days before returning to normal levels. It thus seems wise to prohibit diving during this period.

   b. If any neurological residue persists after 6 months the diver should be advised to stop diving altogether, due to an increased susceptibility to future damage by an already hampered nervous system.

5. Prevention of accidents.

   a. Training in all emergency procedures in diving should be performed so regularly and so strictly that it becomes a second nature.

   b. Diagnosis of emergency procedures should be the first priority of the examining MO. The Doppler system using ultrasound to pick up bubbles after supposedly safe dives could in the future provide help in discovering, for exclusion, bends-prone divers.

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Provisional Report on Australian Diving Deaths in 1978
Dr Douglas Walker

Overview Thirteen (13) diving related deaths have been identified as having occurred in 1978, though additional cases may have escaped detection by this survey. There were four (4) breath-hold diving deaths, seven (7) while using scuba, and two (2) with a hose supply of air. The common factor linking the majority of these fatalities was the victim's ignorance of the dangers of the type of activity he was undertaking. There was one instance where a totally unpredictable acute medical emergency was the critical factor, the probable outcome being death, even if correct buddy procedures been followed. In two cases the buddies were present and offered immediate assistance and deserve commendation despite the fatal outcome. According to available evidence, none of the victims were trained or experienced nor had an appropriate buoyancy aid. Four of the scuba divers managed to drop their weight belts and two also attempted to ditch their scuba backpacks. One became entangled in the straps. Both the hose supply victims died because their hose connections parted, causing them to receive water inhalation with their next breath. It is apparent that the seeming simplicity of breath-hold, scuba and hose-supply diving results, even nowadays, in people neglecting to obtain competent instruction in the skills required to survive misadventure, and even more required in order to minimise the risk of getting into a dangerous situation.

Brief Case Reports

As in previous reports these notes are based largely on the evidence presented at Coroners' Inquests, though such reports are not yet availabe for tow of the fatalities. Such information sourses usually contain the significant facts necessary to reconstruct the cirtical path of the events and the factors influencing this outcome rahter than survival. Where the Coroner has accepted the depositions of evidence but not actually questioned the witnesses there is a greater pobability that there will be omission from the record of some desirable information thought unnecessary for the Coroner's consideration in deciding that the death was "natural, unfortunate and accidental". The very thourough and efficient nature of investigations by interested Coroners is a confirmation of the value such personal involvement to complement to basic facts of the case detailedin depositions by witnesses. The true experience of bothe the victim and his companions is not always elicited, unfortunately, though lack of a clear statement almost certainly indicates the absence of certificates of attainment and training. The type of buoyancy aide, though obviously known, is usually not recorded. It is suggested that in reading theses reports one imagines the different secnario that could have been followedhad all those involved work effective buoyancy aids.

Case BH 78/1
It was the usual practice of this young man, aged 27, to dive off his father's boat to attach the line to a rock mooring. This mooring was submerged and lacked a float. The tide was high and it took him three short dives to locate it. His father shouted to him to give up the search and they would use an anchor, but he seems not to have heard this and he was seen to submerge once more. After a short time it was noticed that he was spending an unduly long time underwater and two people dived in to search for him. The body was discovered lying on the sea bed, at a depth of 7.5 metres (25 feet), still wearing the weight belt and other equipment. He was described as being a good swimmer and a skin diver with five years experience. It is highly likely that this was a post-hyperventilation blackout drowning, an ever present danger to breath-hold divers seeking extended time underwater.

SOLO. NO WET SUIT. COLD, ROUGH WATER. FATIGUE. ALCOHOL. FAILED TO DROP WEIGHT BELT. POST-HYPERVENTILATION BLACKOUT.

Case BH 78/2

When these two fishermen found that they were unable to raise one of their lobster pots, one of them, aged 30, made a breath-hold dive to free it. He surfaced to report finding the pot, then dived again. This time, however, he failed to return to the surface. The other fisherman then dived but was unable to see him so returned to the nearby beach in his boat and asked two swimmers to help him. They found the victim entangled in the rope that was attached to the pot, which was caught between rocks. The body was then brought to the surface by pulling on this line. The victim's experience is unknown, but as he had brought a wet suit, goggles and fins with him it is likely that he had made such dives previously and was confident of his ability to undertake the freeing of a pot in 9 metres (30 feet) of water. His friend considered him to be a competent diver.

SOLO. ENTANGLED IN ROPE. POST-HYPERVENTILATION BLACKOUT

Case BH 78/3

This group of four friends went to the sea for a swim but had only two face masks between them. They decided that one should be worn by the most experienced while the others had the other mask, using it in turn. When his turn came the victim, aged 19, decided to keep near the other diver as he was not a strong swimmer. The experienced swimmer, however, saw a squid and swam underwater after it. When he surfaced he saw the victim about 1 metre (3 feet) away, standing waist deep in the water, and after his next dive saw him swimming again, about 6 metres (20 feet) from the water's edge. He then swam a further 1.5 metres (5 feet) and looked once more. His friend was no longer visible. An immediate but unsuccessful search was made. Eventually the body was discovered on the sandy sea floor with the mask still on and the snorkel still held in the mouth. He had not been wearing any weight belt. At the autopsy it was discovered that a congenital type cerebral artery aneurysm had ruptured, this causing subarachnoid haemorrhage. There was no history of previous ill health to give warning of the presence of this condition.

SURFACE SEPARATION. CALM, WARM SEA. NO BUOYANCY VEST. NO WEIGHT BELT. SILENT SUDDEN DEATH FROM SUBARACHNOID HAEMORRHAGE.

Case BH 78/4

Fishermen, when keen, will let nothing keep them from their prey. This man of 46 was also a good swimmer so he bought a speargun so that he could really get in amongst the fish at a good spot he knew. A few days later he decided to try out his new acquisition. He entered the water from rocks, wearing shorts and goggles but without snorkel or fins. The speargun was attached to him by a line, though he held it in one hand on this, his first dive. Soon after entering the water he found that the swell had increased due to a change in wind direction, tending to sweep him away. A friend saw what was happening and ran to fetch a rope, which he threw to the victim. However, despite entreaties, he would only grasp it with one hand while holding his new gun in the other. The power of the waves soon proved too great and he was drowned. Although included in this survey, this victim could equally be regarded as a swimming accident. It illustrates the sad result of misreading the sea conditions and of fixing on the wrong priorities in an emergency situation.

SOLO. INEXPERIENCED. ROUGH WATER. NO SNORKEL. NO FINS. NO BUOYANCY VEST. ALCOHOL. FAILED TO DROP SPEARGUN SO ONLY ONE HAND FOR RESCUE ROPE. NO INQUEST CONSIDERED NECESSARY.

Case BH 78/x

The snorkel is usually considered a simple and foolproof aid to surface swimming, one that requires no instruction in its use. Occasionally this is disproved and a fatality occurs. The victims sometimes being children.

In this instance a child of 8 years was snorkelling in 1 metre (3 feet) of water in a lagoon, watched by his parents. They lost sight of him and assumed that he had left the water to play elsewhere. Unfortunately they were wrong, for a snorkeller chanced to find the body lying on the bottom. The victim was in such shallow water that it had been assumed that he would have been able to stand up if he got into any difficulties. All his equipment was on but the snorkel did not have a mouthpiece. Presumably water was inhaled and a very natural panic reaction blotted out rational action before unconsciousness and death intervened.

SOLO. CALM, SHALLOW WATER. SNORKEL WITHOUT MOUTHPIECE. INCIDENT UNOBSERVED.

Case SC 78/1

This 17 year old boy bought scuba equipment to improve his retrieval of golf balls from the water traps on the local courses. It had previously been his practice to locate them by walking with bare feet in likely areas. Two days after this purchase, accompanied by a friend, who had recently come out of hospital and was still wearing a back brace, he went to a dam on a nearby golf course. The friend noted the presence of a profuse growth of water weeds and tried to persuade him not to swim there but he entered the water and started towards a small islet 15 metres (50 feet) away. However after going only about 5 metres (16 feet) he surfaced and screamed for help, then disappeared again underwater. The friend was naturally unable to effect his rescue, being limited by his disability. The police divers were called and even they found the conditions dangerous and body recovery difficult, by reason of the water-weed. It was probably the victim's first ever dive with scuba, but this is not known with any certainty.

SOLO. UNTRAINED. NEWLY PURCHASED EQUIPMENT. NO BUOYANCY VEST. NO FINS. BARE FEET TO FEEL FOR GOLF BALLS. ENTANGLED IN WEEDS IN DAM. FAILED TO DROP WEIGHT BELT.

Case SC 78/2

This diver's buddy had a C-Card certification and 10 months diving experience. The victim was considered a poor swimmer and an inexperienced scuba diver. Indeed his buddy stated later: "Before the dive I showed him the elementary safety precautions but he got into difficulties". They spent time snorkelling, then donned their scuba equipment and had a dive, surfacing about 35 minutes later when low on air. They started back towards the shore, on the surface, with the buddy leading. The sea was now choppy, limiting visibility to 1-1.5 metres (4-5 feet). Near to the shore the buddy looked back but was unable to see his friend, so got up on a rock to obtain a better view. He saw him about 45 metres (150 feet) away, apparently swimming towards him, so re-entered the water and swam to join him. When he found that he could not locate his friend after a search, he gave the alarm. A full search was organised but soon had to be abandoned because of the very poor visibility that had developed. The body was found floating the next day, supported by the empty tanks and without the weight belt. He was 24.

UNTRAINED. SECOND USE OF SCUBA. POOR SWIMMER. FEARFUL OF DEEP WATER. NEWLY PURCHASED EQUIPMENT. NO BUOYANCY VEST. CHOPPY SEA. POOR VISIBILITY. SURFACE SEPARATION. HAD CONTENTS GAUGE BUT RAN OUT OF AIR.

Case SC 78/3

Having recently completed a scuba diving course these two divers planned a dive in a small neighbouring bay. They surfaced after 45 minutes underwater to find themselves far out from shore, in the turbulent water at the mouth of the bay. The water here was 15 metres (50 feet) deep, which was more than they desired. They decided to return towards shore to quieter and shallower conditions, by swimming underwater. However during descent the buddy, who was leading, found himself too low on air to continue and was forced to return to the surface. Although they had agreed that separation meant that both should return to the surface to regain contact, the second diver failed to surface, his buddy being forced to conclude that he had continued alone towards shore underwater. There was poor visibility so the victim could have been unaware that his friend, who led, had ascended. Neither diver wore a buoyancy vest or had a contents gauge on his tank, though such had been used during their training course. The buddy on the surface raised the alarm when his friend failed to surface, his calls bringing others to the scene: he himself was out of air and exhausted so had to leave the search to others.

The body was found on the sea bed in about 15 metres (50 feet) of water, the weight belt off and lying across the air hose to the demand valve. The mask was pulled down from the face. The speargun, which he had been carrying, was found nearby. The visibility was so poor that the search had to be done by touch rather than direct vision. The experienced diver who found the body was unable to raise it until he had first cut the webbing to ditch the backpack, but it is not stated what prevented him from using the quick-releases that are usual on such equipment. This equipment was later recovered and tested but no record of the results is in the records: presumably therefore it functioned correctly.

For a very recently qualified diver to become out of air at 15 metres (50 feet) depth in nil visibility, and while alone, would have been an extremely dangerous situation even had he not also been tired and troubled by rough water. The victim was aged 21.

TRAINED. INEXPERIENCED. ROUGH WATER. NO BUOYANCY VEST. OUT OF AIR AT DEPTH. SEPARATION. POOR VISIBILITY. MASK DISPLACED. WEIGHT BELT DROPPED.

Case SC 78/4

Four friends went on a holiday together. One day they hired a boat and some scuba equipment, kitting up in the boat at the dive site. One of the group had some ear trouble and swam on the surface only while the three others prepared for their dive.

The most experienced one instructed the other two on the use of the equipment while on the boat. The victim-to-be claimed to be experienced, but was apparently far from being so. For the other diver, this was his first ever scuba dive. They checked that they all had their air turned on, then made their water entries by backward roll off the boat, fully dressed except for fins. The victim was the last to enter the water, apparently leaving his fins in the boat. He made a brief return to the surface near the boat, waving his arms in an apparent expression of distress before again disappearing beneath the surface. There was some swell and current, murky water greatly reduced the visibility. When last seen he did not have the demand valve in his mouth.

There is no evidence that any of this trio had either snorkel or buoyancy aid. An immediate search was made when the victim's alarm and immediate disappearance were noted, the more experienced diver being joined by nearby divers. The body was found on the sea bed several hours later, minus mask and the 7 kg (16 lb) weight belt and with the arms seemingly pinned behind his back by the webbing of his scuba set. No evidence was presented to show whether the quick-release functioned on this equipment or whether it had been tied in such a way as not to be easily loosened. Subsequent testing established that the scuba set functioned correctly. At the autopsy, fresh middle ear haemorrhages were noted. The victim, aged 22, may have been suffering some sea sickness discomfort before diving. As the neophyte diver of the trio entered the water with apparent excess weights and no fins, and found that one of the fins he was given was uselessly loose, it is indeed fortunate that he lived to say: "I went through everything that (my friend) showed me (before entering the water) because I had never dived before". Somewhat naturally he remained clinging to the side of the boat and made no attempt to join in the search. Water depth was 7.5 metres (25 feet). Lack of fin-power was one of the critical factors, negative buoyancy and middle ear barotrauma from an uncontrollable descent being similarly lethal in their effects.

UNTRAINED. INEXPERIENCED. HIRED EQUIPMENT. NO BUOYANCY VEST. OVERWEIGHTED. ENTERED WATER WITHOUT FINS ON. DITCHED WEIGHT BELT. ARMS TRAPPED WHILE DITCHING BACKPACK. EQUIPMENT HIRED TO UNTRAINED DIVERS. ONE (SURVIVING) WAS USING SCUBA FOR THE FIRST TIME. ONLY INSTRUCTION WAS IMMEDIATELY BEFORE WATER ENTRY FROM BOAT.

Case SC 78/5

Because he had recently completed a diving course and shown himself to be a good student, this 21 year old diver was included in a boat dive with five more experienced divers. As events turned out he made his descent in company with two others, one of whom retrieved the fin he lost during descent. When this diver returned the fin, the victim had reached the sea floor. At 12 metres (40 feet), the victim indicated he wanted to buddy breathe with the buddy still present. There was no apparent sign of any panic and air was seen coming from his regulator. After a couple of successful exchanges there was a reluctance to return the mouthpiece to the donor. While the donor was taking a necessary couple of breaths the victim was seen to go suddenly limp, probably following inhalation of water. The victim made no attempt to inflate his CO_2 vest, drop his weight belt, or start ascending. It is not known why he desired to buddy breath at this time. It seems that death struck as unexpectedly for the victim as for his buddies. These two divers brought him to the surface, ditching his equipment, before getting him into the boat. The equipment was recovered later. Resuscitation failed to restore him to consciousness and although he reached hospital he died from the effects of water inhalation and cerebral anoxia the next day. Although he had a history of easily induced concussion, which he had withheld from the doctor at his “diving medical”, this is unlikely to have been significant to his decease. The coroner’s remarks concerning dangerous sports are reproduced later in this report and are worthy of consideration by all instructors and dive leaders, or even taken as a philosophy for living.

NEWLY TRAINED. VERY INEXPERIENCED. EQUIPMENT CHECK BEFORE DIVE. LOST A FIN DURING DESCENT. UNEXPLAINED PROBLEM ON SEA FLOOR. EXCELLENT BUDDY RESPONSE. BUDDY BREATHING PROBLEM. DID NOT INFLATE VEST OR DROP WEIGHT BELT. SUDDEN UNCONSCIOUSNESS. DELAYED DEATH.

Case SC 78/6

Once more the surface is shown to be a Zone of Danger. These two divers had been scuba diving, the victim watching his friend spearfishing. They became low on air and ascended shortly after the buddy shot a fish that escaped into a cave with the spear. The buddy told his friend to either wait where he was on the surface or to start to snorkel back to their boat, 60-90 metres away. He then dived to retrieve both fish and spear, surfacing to find no trace of the other diver. Having regained his boat without trouble he then noticed a man on the shore who indicated that there was a diver in trouble near the rocky shore, so he cut the anchor line and drove to the place indicated. There he found the victim floating minus all equipment except for his wet suit. The victim was too large a man for him to get into the boat single handedly so he sent a Mayday call for help.

A police boat soon arrived and, after towing the other boat a safe distance from the rocks, one of the policemen came aboard and helped get the victim on board. Resuscitation, in the small boat, was difficult in the rough conditions. Shortly after this a helicopter rescue team arrived but it was not possible to restore signs of life. The victim was aged 40 and was said to have been navy trained in time past, but he had not undertaken any diving for several years. The water was choppy at this time. The equipment was never recovered for test and the suggestion that his snorkel may have separated into two pieces cannot be evaluated. He had no buoyancy aid.

TRAINED. FOUR YEARS SINCE LAST DIVE. CHOPPY SEA. NO BUOYANCY VEST. SURFACE SEPARATION. SURFACE PROBLEM. OUT OF AIR. DITCHED ALL EQUIPMENT. FOUND FLOATING DEAD.

Case SC 78/7

The sudden tragic turn of events that occurred during this seemingly simple training dive underlines the necessity to correctly assess all possible factors before starting any dive, especially where those involved lack experience in the type of diving to be undertaken. In this case, four divers attended a dive in a dam. A greater number of club members had been expected. The diver, who was both instructor and dive leader, took the three others to a small islet, then dropped a shot line from a 2 gallon float. This line was 22 metres (75 feet) long and weighted with a weight belt. Although it was not expected to touch the bottom here, the line appeared to become firm on something underwater. While he remained on the islet with one of the part-trained divers, the other two swam out to the float and commenced their dive. The victim had been receiving club instruction in scuba diving for about 7 months and had made several sea dives, possibly to 15 or 18 metres (50 or 60 feet), but was not yet a fully qualified diver. The experience of the buddy is uncertain, but possibly similar. They were joined together by a buddy line and wore buoyancy aids. The victim was leading the descent, holding onto the line with one hand and holding a torch in the other. This he shone on the second diver’s face during descent. The water was cold and dark, light not penetrating below 3 metres (10 feet), so the second diver could not read his depth gauge, his ears being the only indicator of their descent.

Those ashore saw the float submerge, reappear, then descend again for a period of time. When it finally reappeared it was crushed, which alarmed the observers. They immediately rowed to the float, arriving as the survivor diver “bounced up” from the water. The instructor dropped another marker, presumably noting that the original one was free, and dived in an attempt to locate the missing man, but his search was unsuccessful. Several subsequent police diver searches were similarly unavailing and it was a week before the body was located on the dam floor at the foot of a large tree, at a depth of 36 metres (120 feet).

The buddy described how their descent halted before reaching the end of the shot line. The victim (leader) then started to shake and called out the buddy’s name. This alerted him to the fact that the other no longer had the demand valve in his mouth, so he reached forward and replaced it. This failing, he offered his own mouthpiece. Believing that entanglement had occurred in the line or in the branches of a tree, he tried to cut his friend free with his knife. This included severing the shot line and float. Next he tried to drag the victim free by inflating his own vest. Becoming alarmed for his own safety he cut the buddy line and ascended, the rate becoming such that he had to puncture his vest (the type of vest was not stated, but it worked efficiently) to slow his ascent.

The subsequent very thorough investigation established that the victim had mentioned some ear symptoms earlier that weekend, had 12 kg (20 lb 10 oz) on his weight belt, and had suffered bilateral perforated ear drums during the incident (evidence noted at the autopsy). As the float was insufficiently buoyant to support the divers they could not use the line to arrest their rate of descent, and neither could the line fulfil its secondary purpose of being a stable reference point in a mid-space, nil-visibility situation. The excessive weights would cause uncontrollable descent and the victim would had have no chance to equalise his ears before pain and vertigo completed his disablement. There would be cold, darkness, spatial disorientation, entanglement, ear pain, vertigo from cold water entering the middle ears and loss of air supply, rapidly followed by inhalation of water. A fatal conclusion was unavoidable in these circumstances. The way the buddy reacted was remarkable and deserving of high commendation. The victim’s vest was later found to lack a CO_2 cylinder. The coroner made recommendations indicating his view that all dives below 9 metres (30 feet) should employ the full RAN diving procedures: lines to the surface, buddy lines, a ready kitted up surface diver on standby, etc. Such precautions are hardly likely to gain wide currency outside disciplined organisations, but at least dive planning should include correct weighting, having regard for the equipment worn, the intended depth, dive purpose and whether salt or fresh water. An effective buoyancy aid should be worn, and at least one of every diving pair should be sufficiently experienced in the type of diving being undertaken to be able to predict and manage all probable problems. And to be of more than token value, any shot line should be firmly fixed, both top and bottom. If you fly a sky anchor, fly it right!

PARTLY TRAINED. INEXPERIENCED. DIVING IN FRESHWATER. COLD. DARK. OVERWEIGHTED. INADEQUATELY SUPPORTED SHOT LINE. UNCONTROLLED DESCENT. KNOWN TO HAVE TROUBLE EQUALISING. RUPTURED EARDRUMS. NO CO_2 CYLINDER IN BUOYANCY VEST. ENTANGLEMENT IN LINE AND TREE. FAILED TO DITCH WEIGHT BELT. BUDDY AVOIDED PANIC, CUT SHOT LINE, INFLATED VEST BUT COULD NOT FREE VICTIM. CUT BUDDY LINE TO ESCAPE.

Case H 78/1

These two divers were experienced hookah divers, but neither of them had ever received instruction in hookah diving. The victim, aged 27, had been diving for possibly 5 years and his buddy for 10 years. Both had usually dived with different partners, this being only their third dive together. They had been using home-constructed hookah units, as was apparently the local custom. On this occasion, both the unit and the boat belonged to the buddy. The was 10 years old. They proceeded to spearfish, though with only one gun between them, in 15 metre (50 feet) deep water.

They each had 60 metres (200 feet) of air hose from the compressor, which was left working in the unattended boat. Each diver checked his own equipment. They wore two weight belts each, their normal custom. About half an hour after starting the dive they saw “the first decent fish” they had encountered so far and the victim was seen to start to drift after it. Due to poor visibility, of about 3 metres (10 feet), he was lost from sight. The buddy held back so as not to frighten the fish and spoil his friend’s chances of a kill. After swimming about a further 6 metres (20 feet) he noticed that his air supply had improved and supposed from this, that his friend must have returned to the boat. As he started his return swim he soon came upon the victim on the sea bottom, not far from where he had last been seen. His hose was not entangled in any way. The victim’s demand valve was not in his mouth and he still wore both weight belts. His facemask was still on, though there was water and blood in it. The victim was too heavy for the buddy to raise so he returned to the boat and pulled the body up by the air hose, which was still attached to one of the belts. Resuscitation was unavailing. The demand valve and the short length of attached air hose was later recovered from the incident site and all the equipment was tested.

Investigation revealed that the brass snap-lock connection had developed some rust and deposits during its years of service and failed to lock home securely unless extra pressure was used to mate the pieces. The general condition of the equipment was described by the police expert witness as “poorly maintained”, with specific comment to nearness of the air intake to the engine exhaust. However although the air conditions would have encouraged carbon monoxide to be drawn into the intake, this was not a factor effecting the incident. The weight belts totalled 12.8 kg (28 lb 5 oz), and although one had an efficient quick-release the other had been secured by passing the running end of the belt through the buckle itself, the belt having a nick that engaged the buckle, then back through the buckle. Sea conditions were calm.

It is supposed that the victim exerted some added strain on his hose, possibly catching it with his elbow while loading the speargun, and caused the connection to separate. His first intimation of trouble would be when he inhaled water instead of air, for the non-return valve would be no safe guard against such a line disconnection. As the demand valve mouthpiece and short hose section were not attached to his equipment, they were found separately from him. Being over weighted, untrained, and taken by surprise, his chances of reaching the surface were virtually nil. The coroner itemised all these points in his summing-up.

UNTRAINED. EXPERIENCED. NO BUOYANCY VEST. OVERWEIGHTED. POOR VISIBILITY. NO QUICK RELEASE FOR WEIGHT BELT. SEPARATION UNDERWATER. SUDDEN AIR LOSS WHEN HOSE UNCOUPLED DUE TO CORROSION. UNATTENDED BOAT.

Case H 78/2

This crewman, on a foreign ship, undertook to clear the blocked water inlet pipe opening. The blockage had occurred while his trawler was moored at a wharf in port. The work depth being only about 3 metres (10 feet), though water depth was 15 metres (50 feet). It is uncertain whether he had actually used this particular equipment before despite his protestations of experience and belief in his own ability. The apparatus was rarely used and seemingly not the responsibility of anyone to maintain in good order. For his task he wore neither weight belt nor lifeline. The facemask was of the gas mask type, firmly maintained in position by straps, such that it would be impossible to quickly remove it in an emergency. The air hose was of two lengths joined over a metal tube with the aid of wire. Nobody was in specific control of the compressor but a crew man was tending the air hose.

The diver was seen to surface and hold up a handful of jellyfish, presumably from the inlet, and then to submerge again. It was supposed he was checking whether the job been completed successfully or not. The line tender noticed that an apparently excessive length of hose was being paid out, and later realised that the diver had been lost. A police diver search later found the victim on the harbour floor beneath the ship. The hose was disconnected at the junction and it was supposed that the diver’s lack of a weight belt would have necessitated him pulling hard to get round the hull and he put too much strain on the connection, resulting in its coming apart. His mask would have immediately flooded with inevitable drowning of the unfortunate diver. The lack of a lifeline made any surface assistance quite impossible, in fact any pull on the airline would have caused just such a hose separation that occurred. There was a current working at the critical time of the dive.

UNTRAINED. PROBABLY INEXPERIENCED. POOR EQUIPMENT. UNSAFE MASK. NO WEIGHT BELT. NO FINS. NO BUOYANCY VEST. AIR HOSE DISCONNECTED.

Discussion

The four breath-hold divers illustrate well known danger factors viz. entanglement, inability to survive in rough water, hyperventilation resulting in anoxic loss of consciousness and sudden disabling illness. None of these are survivable in the absence of immediate appropriate assistance by another person, and all these victims were alone and without buoyancy aids at the critical time.

The scuba divers died as a result of a range of problems. Significant common factors being the inexperience of the victims and their lack of effective buoyancy aids. It can be reasonably surmised that the toll could have been higher, several of the buddies being in high risk situations. It is noteworthy that death, when it strikes, is very rapid. Water inhalation appears to be the major road to the Mansions of Eternity, an event whose consequences are hard to escape. Weight belts were successfully dropped by four divers, two of whom also intended to ditch their scuba sets. One succeeded but the other became entangled with the webbing during his attempt and drowned thus. It is debatable whether such ditching was appropriate action in the circumstances: the presence of effective buoyancy aids would have ensured surface safety, and the tank is either heavy with air, or light and buoyant if empty. There are not any adequate descriptions available concerning the quick-release aspects of the sets involved. Two fatal cases were associated with excessive weighting of the victim, and some of the buddies are thought to have been similarly at risk.

The inexperience of these unfortunate divers in no way prevented them from obtaining scuba equipment. That basic training in scuba diving was given on two occasions while actually in the boat awaiting water entry, is an alarming piece of information for those interested in reducing fatalities and indicates that many divers remain unconvinced about the necessity for training before starting to dive.

In two instances ear troubles were shown to have been significant. In both cases, this being the result of uncontrolled descent due to overweight. These cases have been described in detail and involve a number of other important breaches of safe diving practices.

In conclusion, one cannot better the words of one coroner, who put the problem in perspective when he stated: It would be a simple matter to take the view that the deceased, by engaging in this particular recreational pursuit with its inherent dangers, had in some way brought about his own demise. Much the same sort of considerations would apply to those who, for recreational pleasure, pursue such activities as hang-gliding, parachute jumping, mountain climbing and the like. But, in all these seemingly dangerous activities, where accidents can and do occur, the question must always be asked: "How well trained, instructed or prepared was this person for the particular activity in which he was engaged?" It would seem a perfect summary of what diver training is all about.

Acknowledgements

This report would not have been possible without the assistance of many persons and groups, and in particular the generous and continued assistance of the Attorney-General's and Justice Departments in every State. In addition the growing interest and assistance of Water Safety Councils and the National Safety Council is gratefully recorded.

Project Stickybeak

Readers are requested to support this investigation by sending reports of diving-related incidents, however mild and apparently well known they may seem to the person reporting to the address given below. Confidentiality is assured. Although non-fatal incidents are not the subject of this report they are of great importance and will be reported upon at a later date. Safer diving is the result of learning from past experience, and sharing of such experiences can improve the recognition of developing risk situations while it is still possible to influence the outcome to a safe conclusion. No problem can be remedied until it has been identified as being a problem, and Incident Reports are essential for this to occur. Please write:

Dr Douglas WALKER
PO Box 120
NARRABEEN NSW 2101

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Whales: Dr Sylvia Earle on Radio

In a recent ABC radio interview Dr Sylvia Earle was questioned about the ability of whales to dive deep and long, and whether they are intelligent. Her brief remarks pointed out the interesting facts now known and the much larger corpus of information of which we are ignorant. Apparently the song of the whales (Humpback) evolves during the season but is common to all the whales in that area for the season, changing completely the next year. It is thought that the sound is created by air movements within the air passages and no air is expelled. The sound can be heard for possibly hundreds of miles by other whales and can be experienced also as a painful vibration by a diver near a "singer". (It has taken the electronic era for human pop songs/music to reach this intensity, she might have added, but didn't!). The humpbacks have also invented bubble-net fishing, swimming round dispersed krill exhaling bubbles to frighten them into a tighter packed school, then rising in the centre to feed. The ability they have to descend into cold, deep water for prolonged periods of time is not fully explained, for till recently, biologists tried to understand living things by examining the dead only. Having seen the young, and old, whales play and come to realise the individual personalities of the whales, Dr Earle is naturally in the forefront of the campaign to stop their slaughter.

Decompression Sickness: Four brief cases

Dr Douglas Walker

There is a general, persistent, and probably irradicable belief among most experienced divers that their years of diving without having recompression therapy indicate that not only are their diving techniques safe but that there is a margin of safety present that allows discretionary variation without penalty. This belief illustrates their possibly natural lack of understanding of the basis upon which the conventional diving tables are constructed. Both Naval and Commercial tables are, in general terms, designed to accommodate diving by healthy young men making vertical ascents and descents at specified rates, dive depth and duration being accurately known, and work being of a moderate intensity. Any “decompression stops” will be taken at accurately measured depths, confirmed by trained surface support divers. In case of doubt about depth, time, environmental or work factors the appropriate increase in table “obligation” will be followed. Under such circumstances a few cases of decompression sickness will still occur but will be notified and treated without delay. Any suggestion that such a description is appropriate to many dives conducted by recreational or professional divers (other than those in Governmental employ or of exceptional carefulness) would stretch credulity, although many divers certainly approximate adequately and suffer no apparent symptoms. Modern beliefs concerning decompression incline to the acceptance of pressure-reduction induced bubbles forming even when following the present day diving schedules, the “bubble score” relating in general to the likelihood of developing symptoms. It is known that there is a wide and unpredictable variability in symptom occurrence after identical dives, that frequent diving increases tolerance of a given dive schedule, this tolerance being rapidly lost after the diver ceases such dives, while the threshold for “noticing” symptoms of decompression sickness is effected by a multitude of factors. The following cases are presented to indicate that the Mantle of Immunity can wear thin, many years of diving notwithstanding. As the ill effects of many year’s of “rough diving” have still to be evaluated, the wise diver will continue to try to avoid troubles, known and unknown, by heeding even the most gentle of symptoms.

Case A

Aged 35 and with a 14 years diving history without clinically diagnosed bends, this hookah diver spent 7 hours at 21 metres harvesting abalone. Shortly after he surfaced he started to experience severe symptoms, which he apparently hoped would go away. Despite his disablement he remained physically active, driving his boat and then his car as he made his way home, apparently in the company of others who one would expect to be able to assist him if allowed. The severity of his alarm ultimately forced him to call an ambulance and attend a Hospital for recompression therapy. His residual hearing deficit would seem to be a slight price to pay for his type of diving. (This case is reported more fully in the separate article).

Case B

This 43 year old diver with 15 years of hookah diving experience undertook three dives to 30 metres in a 2 hour period. Their individual duration is not known. During this time he was spearfishing, this being his usual habit. Symptom onset was 1 hour after his last dive.

Case C

This diver, aged 30, had 13 years experience of compressed air diving without receiving recompression therapy, the purpose of his diving being searching for shells. He was diving alone in an area well known to him and for which the depth had been triple checked on previous occasions.

The dive plan was for 50 minutes at 70-80 feet with stops of 5 minutes at 20 feet and 10 feet. In the event, because he began to feel cold, the actual dive was 45 minutes at 65-82 feet, with the planned "stops" unchanged. About half an hour after surfacing he experienced a slight pain in his right knee, 4 hours later an aching right shoulder. His right ear also felt painful. He apparently first contacted medical aid 12 hours after surfacing and started treatment over 48 hours post dive, as explained below.

Some modification became necessary in this apparently clear story after additional facts were revealed. In fact there had been three previous occasions where mild "bends" symptoms had been recognised as occurring by the victim, these producing numbness in his forearms. One was treated at a Hospital with 1 ATA Oxygen overnight. He also revealed that the lesser dive time "possibly made me get a little slack". It is probable in fact, that dive maximum was 85 feet "for a very short time", and he actually ascended direct to his boat to place his heavy "goody bag" in it, then descended to make his scheduled decompression stops. There had been dives on each of the previous two days, surface intervals being 24 hours, the first being 35 minutes, at 80 feet, with a 5 minute stop at 10 feet, the most recent for 50 minutes at 80 feet with 5 minute stops at 20 and 10 feet. His daytime job, performed as usual before this incident dive, involved heavy physical work with his arms. Depth were stated with certainty, the diver having seen others get into trouble through relying on DCM or inaccurate depth measuring. His actual actions after symptoms developed were to contact the nearest hyperbaric facility after 12 hours, to be told to contact the Hospital. However before he reached the Hospital his symptoms had abated so he made his way back home (150 miles), as detention for observation would have caused his workmates to lose time because of his absence. However on the second morning back he could no longer ignore his symptoms and therefore attended for his treatment. This was an Oxygen table (2 and a half hours), followed by oxygen/ air alternate hours for 12 hours. Mild joint pains persisted for 4-5 days after, and occasional discomfort still occurs. He has not yet resumed diving, though he is at his regular work. He is a careful diver and never makes dives requiring decompression (now) when using hookah air supply unless he wears a scuba supply as back-up in case there is a hookah problem during his "stops".

Case D

This 28 year old scuba diver of undetailed experience was crayfishing. He made a 70 foot dive for 1 and a half hours, had a 1 and a half hour surface interval, then made a further dive at 70 feet, for 1 and a quarter hours this time. There were no decompression stops with either dive. Pain in the left shoulder and formication of the upper anterior chest occurred 5 minutes after surfacing.

Comment

It is apparent that none of these were simple, single depth dives of the type for which the tables were designed and against which they had been tested. It is very likely that these divers habitually followed similar dive patterns, and believable that they had not accepted the possibility that they had suffered mild "bends" symptoms on previous occasions. The cases are presented as a warning that decompression sickness lurks in the background and extra exertion; cold; mistakes with depth/time/rate of ascent; tiredness; or some other factor, may result in a penalty that the victim cannot shrug off. Spinal bends have terminated the careers of "tough" divers and will do so to others in the future, as well as some careful divers. A free and relaxed relationship with the Dive Tables can go remarkably sour without the diver feeling he deserves his fate.

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Diver tells of his Black Friday bends ordeal

Jo Wiles

(This article is reprinted by kind permission of The Age, Melbourne)

Allan Reynolds was “bent” for the first time at Easter and he did it in text-book style. A bubble in the brain gave the 35-year old professional abalone diver stabbing pains in the joints, a searing headache, tunnel vision and the “chokes”. He says it was too dark to see if he went blue in the face, but he did go a bit loco and is still deaf in one ear.

Mr Reynolds was struck by the “bends”, or decompression sickness, about 15 minutes after his final dive off Cape Schanck on Friday. It was supposed to be his Good Friday, but after seven hours diving and only 13 bins of abalone, it turned out to be his Friday the Thirteenth. He ended up spending more than two hours in a decompression chamber at Prince Henry’s Hospital after steering his Sharkcat across Westernport Bay and then travelling home in a car from Hastings.

A diver for 14 years, he said yesterday he had tried to ignore the first pains of his “bends” which started in his right leg just off Flinders. “When you know it’s a little bubble trying to force its way through a joint, you’re more worried about that than the pain,” Mr Reynolds said. “I suppose you’d call it a stabbing pain. It peaks, then goes, then comes back again. After that, I got this incredible headache – like a top notch bad migraine – and my sight went. It made it terribly difficult to drive the boat with things looking watery.”

By the time Mr Reynolds, his wife, Arleen, and brother-in-law John Fenske, had reached Hastings and started back on the road to Melbourne, the “chokes” had set in. “I just couldn’t get enough air. All I wanted to do was to get back here, get an ambulance and go to the decompression chamber. I was out of it.” He said that he was so disorientated by the bends that he could not remember his friends’ names or things he was saying. “You know your mouth runs away without your head in gear. You start shouting and yelling because you’re deaf and you keep shouting.”

Mr Reynolds, who is still deaf in his right ear, said he believed he had misjudged the depth of his last dive and ascended too quickly. Decompression sickness is caused by gas bubbles which form in the body tissues if a diver rises to the surface without taking proper decompression procedures.

. . . .

(This story was also reported by at least two other papers, these providing the following additional details:

He had been diving in about 21 metres from 10 am till 5 pm, collecting abalone. When he surfaced he complained of pains in his arms and legs, his wife reported, and when the party started back in his boat “he could hardly see and it was difficult to make any sense out of him. When we got home, and on the way to the hospital, he was going hysterical. He was totally deaf and desperately gasping for breath. He was yelling and screaming. I was pretty scared”, she said. Dr Gavin Dawson said treatment was at 20 metres depth (gauge) pressure for 75 minutes, then 65 minutes at 10 metres, followed by overnight stay in hospital for observation. He was the 11th bends patient treated at the hospital since the machine was installed 10 years ago.)

“Doing” what comes naturally -
An Air Compressor Seminar reviewed

This particular meeting had been well prepared by the NSW branch of the SDFA and took place in Sydney in April 1979. It was a disappointment, but possibly no surprise to the organisers, that attendances by dive shop compressor operators was less than that hoped for. Under the Chairmanship of Dr Doug Harris the meeting proved of interest to those attending, even if few ended up buying new compressors.

The first speaker was Mr John Bishop of Ingersoll-Rand, his subject being the compressor his firm thought most appropriate for dive shops. His financial fancies as to costlags may have left his listeners somewhat bemused, but convinced that somehow they were on a loss-leader unless they got good tax advice concerning write-offs of their expenses.

Then Dr Doug Walker added a veneer of medical respectability to the matter under discussion by listing some of the nasty “extras” one can get with the air you buy. He refused to be drawn into saying how much oil you could safely inhale without increasing risk of lung cancer above the normal, and suggested that nobody should either accept or use “dirty air” whatever its supposed analysis. His brief attempt to amuse, by telling of the Tasmanian Abalone diver’s advice that use of sanitary pads was cheaper than other more conventional filter material, was capped by one of the audience who related that such divers don’t always remember to remove the plastic bag from around the product, and therefore somewhat reduce the efficacy of the filtration. Strangely, none of the representatives from Industry had used such modifications of basic filtration modes. In fact the description of Hopcalite cartridges by Mr Ralph Warren related to a rather more costly, though undoubtedly more efficient purification system for compressed air. Amazingly nobody collapsed when he stated the cost of the cartridge, and said that the chamber to hold them was not too cheap either. Those present became more wedded to their present methods, it seems likely, after hearing the price of more perfect equipment.

Mr Bob Sparks of Castrol described the function of oil in a compressor so clearly that he invested the matter with interest not hitherto thought likely outside the Corridors of Oil Power. They certainly design oils for every purpose, even a special one for use in coal mine drills. These drills distribute water and oil over their users. This was an unexpected insight into industrial medicine; make the pollution non-lethal but don’t eliminate it! The human body must be tough!

Messrs Barry McMahon and Ross McCleary represented CIG, singing a duet in favour of Aluminium cylinders and only briefly suggesting that the easiest way to get pure breathing air was to buy it from CIG. It became apparent that such cylinders are terribly good but need a lot of tender loving care, such as being unharnessed after diving and given a good fresh-water wash. While this was self evident to CIG it certainly was news to the diving community, which seems to have read the adverts without seeing the small print. It was noted that pressure vessels were ill protected by regulations and the amazing situation existed that an ignorant inspector could bore a hole through the cylinder as the legal test method. Crazy, man, crazy! But a little gentle instruction, and calling a pressure vessel a mobile tank, would solve this problem and also make one Insurable. It was said that any compressor operator could get his air tested by the Health Commission if he knew who to ask, but there was evidently no great effort exerted by any Authority to initiate testing.

continued on page 42

Investigation into Loss of Consciousness in Divers
Department of Energy UK - Statement of interest

The study has established a mechanism for surveying and investigating incidents of medical and physiological importance occurring during operational diving.

1. Summary of incidents studied

Information has been collected concerning 151 incidents. 114 have been studied, the remainder being excluded as RN oxygen dives or decompression table tests.

In 42 incidents the diver lost consciousness. The period of unconsciousness varied between a few seconds and 40 minutes. In 72 incidents the diver did not lose consciousness, but unusual symptoms or problems were reported.

A close similarity has been shown between incidents in which consciousness was lost and the other incidents by comparing the symptoms reported by the diver or his attendants.

No symptoms at all were reported before more than half the incidents in which the diver lost consciousness. Evidence from attendants before the remainder of the incidents strongly suggests that deterioration in the diver's condition often rendered him incapable of helping himself, putting his life at considerable risk. Diver attendance is of paramount importance in ensuring diver safety.

The commonest problems associated with all incidents were related to breathing, and included breathlessness, hyperventilation and difficulty in breathing. Hyperventilation, which may be noticed over the communications system, is the most accurate indicator at present available of a potentially dangerous situation.

Two further groups of problems, including unsteadiness or weakness and neurological problems, cannot be satisfactorily explained by evidence from the retrospective study.

Compression and decompression problems, such as difficulty in clearing ears and pain from sinuses, were largely excluded from the study. Similarly obvious mechanical breathing apparatus may be inadequate for operational use in the North Sea.

The majority of incidents occurred to divers in the age range 21-25 years. There is evidence that psychological unsuitability or lack of experience to cope with unforeseen situations can cause hyperventilation. Psychological problems can affect a diver's performance in other ways, for example by causing inattention.

2. Summary of Causes of Incidents shown by the Study

Below are listed the causative factors thought to be involved in loss of consciousness and the occurrence of other symptoms in divers. These factors are related to appropriate research in the report on the study.

a. Hypoxia or Hypercapnia: Due to equipment problems, particularly related to the magnitude of external breathing resistance and the ability to provide adequate peak flow.

b. Hypoxia or Hypercapnia: Caused by additional external and internal breathing resistance due to increased gas density at pressure.

c. Tissue hypoxia: The effects of hard physical work under cold conditions may increase oxygen demands by the tissues to levels which would require more than maximal cardiac output. Insufficient oxygen would then be delivered to the brain and the heart might fail.

d. Carbon dioxide effects: The respiratory responses to carbon dioxide in normal and abnormal individuals require further study; some individuals, if carbon dioxide retainers, may have a reduced respiratory drive from hypercarboxaemia.

e. Cold: Other research has shown that cold is responsible for inattention or distraction and poor manual performance. It may also have a direct effect on cell metabolism reducing tolerance to work and other stresses.

f. Psychological problems: Especially in inexperienced divers these may result in inattention, confusion and inappropriate actions.

g. Dysbarism: Some symptoms characteristic of decompression disorders have been noted. Some problems may have been due to less obvious dysbaric episodes.

3. Design of Prospective Study

The study should now continue as a Prospective Study, information from which will be more reliable and complete than from the retrospective study. The Prospective Study should also act as a framework for research and investigation of the medical aspects of operational diving. The functions of the Prospective Study are more fully described in Abstract 11 and in the report.

In operating the surveying aspect of the Study a number of reporting systems will be necessary according to the timing and location of accidents and incidents. If the personal attendance of a doctor is not possible, it will be necessary to make use of standard forms returnable from the accident site.

Reports of incidents either in the form of a questionnaire or as the result of examinations by doctors will be returned to the Study Centre where they will be processed in a fashion similar to that of the retrospective study. In the design of questionnaires it will be possible to elicit much more specific information than has been possible from the retrospective study. The study will request reporting from doctors and diving companies of any abnormal incidents occurring during operational diving which might have medical or physiological explanations. It is not anticipated that pure decompression disorders will be included.

At present in the United Kingdom there is no system for the constant surveillance of operational diving for medical and physiological problems, and there is no common referral point for information and advice. The proposed Prospective Study will serve both functions. There will be a computerised register of information about previous incidents and the Study has already begun to use this in defining problems requiring research. The Study will also be able to coordinate medical advice about problems encountered during operational diving.

Operation PANTYHOSE

from: The FISSH Chronicle by "Pappe Topside"
Institute of Diving Newsletter, April 1978

Early this day, all went as if especially ordained. The sea was mill pond in character, and no less than 16 divers set forth on their assigned missions. By noon, radio reports were very encouraging, so I set about a little experiment planned some days previously. The equipment was finally in order, and our four volunteer subjects were currently unemployed. Accordingly, at 1330 hours, Operation PANTYHOSE got under way.

Since we had the one-time occasion to surface the PTC with human cargo a few of us have had deep concern about the reliability of the CO_2 scrubber system of the capsule. Looking ahead to the ever-present possibility that a loaded PTC might have to survive as long as eight hours without ventilation, we cast about for a passive system of CO_2 scrubbing, quite independent of electrical power. Clearly, a system of random scattering of Sodasorb within the habitat was untenable. Likewise, individual closed circuit breathing units seemed inadvisable. How about simply filling a few ladies' nylon hoses with absorbent, and handling them in the capsule? The idea had appeal, despite its naivete, so we launched the project, using two pairs of pantyhose, one black, one red, filled with a total of 8.6 kilos of sodasorb.

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AVOIDING THE BENDS continued from page 5.

Diver education seminars on *Avoiding the Bends* might be helpful. Such a seminar should cover deep diving procedures, standard US Navy dive tables, repetitive diving, avoiding the bends, and decompression sickness and treatment. Ask your club President, Divemaster, or NAUI Branch Manager to consider a seminar like this in your locale.

Finally if ever you feel pain or itchiness anywhere, however slight, following a dive, call your divemaster or instructor immediately. Waiting could possibly aggravate your condition. Your instructor or divemaster will know what to do.

Each diver should carry a list of *important telephone numbers* in case of emergency. A good place to store these numbers is inside your log book or wallet. Make sure your dive buddy knows where these numbers are located. This list of important numbers should consist of local police, state police, local hospital, Coast Guard, and nearest location of a recompression chamber. Your local Branch manager can help you locate these important telephone numbers.

Remember: the US Navy Dive Tables are just a guide. Know the no-decompression limits for sport diving. Modify the tables so that you end your dive well within the limits of the dive table. Play it safe!

. . . .

(Errol Duplessis, NAUI 5307, is a doctoral candidate at Boston University majoring in Physical Education. He is currently Divemaster for the New England Aquarium Dive Club Inc., of Boston, Massachusetts. After graduation he plans to teach college level aquatics and swimming to minority children.

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DECOMPRESSION SICKNESS Continued from page 36

There is no guarantee that therapy will be completely successful, so don’t bet your health against a mess of bubbles.

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DOING WHAT COMES NATURALLY Continued from page 38

This Seminar revealed the existence of some of the complex factors effecting the production of Medically Pure Air for divers. It is probable that divers will only get pure air if they insist on it by only going to those who provide such an article.

<u>ESCAPE FROM THE DEEP</u>

Lt. Phillip Kern, USN
HMI(DV) Daniel E Mane, USN
US Naval Submarine School

(Reprinted by kind permission of the Editor, FACEPLATE)

The USS NUCLEARFISH has just surfaced off the coast of New England and begun her transit of Long Island Sound, making her way toward the submarine base at Groton, Connecticut. Her patrol at an end, she now faces what has historically become the most frequent setting for a submarine accident. In the busy shipping lane, the NUCLEARFISH is accidentally rammed by a merchant ship headed for the open sea. She sinks and comes to rest in 120 feet of water.

The Submarine Rescue Ship HAWK is dispatched to assist the downed submarine. Underwater communications between the submarine and the rescue ship indicate that blowing ballast will not raise the NUCLEARFISH and that her severe starboard list will not allow the McCann Rescue chamber or the Deep Submergence Rescue Vessel to mate with her escape hatch. Deep-sea divers from the HAWK enter the water to investigate and have confirmed the report.

Although the preceding is a hypothetical situation, history has proven that it has happened, and that it may happen again. Large ships often fail to identify the small silhouette of a submarine and, thinking it is a highly manoeuvrable small craft, fail to avoid it.

The staff at the Escape Training Tank at the US Naval Submarine School in Groton, Connecticut, knows that crews will be able to safely exit from stricken submarines like the nuclearfish and be returned to port - they have trained every US Navy submarine crew in the individual Free-Breathing Buoyant Escape Method of Submarine Escape.

Escape methods have been taught at the tank since 1930. A need existed then, as it does now, for training submarine crews in methods of escape in the event that all other methods of rescue fail or are deemed impossible.

When Submarine School students arrive at the escape tank, they change into swimming trunks and go directly to a classroom where they are given instruction in the use of the Steinke Hood. This device protects the escapees head and face from the water, allowing him to breathe easier, alleviate his apprehension, and reduce the incidence of air embolism.

Upon completion of the classroom phase, the students enter the tank and demonstrate that they can safely and expeditiously make an escape from 50 feet through a lock or hatch similar to those on submarines.

The Steinke Hood provides a rate of ascent of 425 feet per minute. Because air embolism is a very real factor at this rate, the student is observed closely throughout his training in the water. The student is also instructed in the proper operation of the escape hatch, or lock. Nitrogen narcosis and air embolism are cumulative effects of exposure to pressure, and too much time spent in preparing the escape hatch can be as damaging to the escapee as improper use of the hood.

Once the student leaves the 50-foot lock (or any of the shallower locks) during his course of training, he is always within reach of an instructor ready to stop his ascent and pull him into a safety lock should he fail to exhale properly or experience trouble. If the student should be afflicted with air embolism, a diving corpsman on continuous duty during tank operation stands ready to initiate medical treatment with a recompression chamber located at the top of the tank.

The individual method of submarine escape has been used in the past and is credited with saving hundreds of lives. The other methods in use are: The McCann Rescue Chamber, a cable-controlled escape lock carried by rescue vessels; and the Deep Submergence Rescue Vessel (DSRV), a mobile escape lock carried by the most modern rescue vessels.

Improvement in escape methods were prompted by the sinking of submarines F-4 in 1915, the S-51 in 1925, and the S-4 in 1927. These disasters led to the development of the McCann Rescue Chamber mentioned above, and the Momsen Lung, which was successfully used in 200 feet of water off Key West, Florida, in 1929. This device was a vast improvement over the Siebe-Gorman apparatus developed in 1914. But, the Momsen Lung had an ascent rate of only 25 feet per minute and provided no protection for the escapee's head, thus making all but experienced swimmers apprehensive and the potential for air embolism great.

In 1956, the "blow-and-go" method of escape was devised. The escapee was still completely exposed to the water and exhaled continuously during the ascent. The method was tested in the open sea in 302 feet of water from the submarine ARCHERFISH off Key West in 1958. It increased the rate of ascent in excess of 400 feet per minute through the water using a life jacket with 46 pounds, of positive buoyancy and relief valves for air expansion. It was a major step forward.

In 1960, Lieutenant Steinke, Officer-in-Charge of the Escape Training Tank, developed a device which protected the head and face from the water. The Steinke Hood was successfully tested in the open sea in 1961 in 309 feet of water from the USS BALLAO, again off Key West. The hood remains the primary method of individual submarine escape and has sufficient buoyancy to carry several people safely to the surface. The "blow-and-go" method is an acceptable back-up technique should something happen to the hood itself.

The escape training tank's primary mission is to teach escape procedures. However, over the years its mission has been expanded to include scuba instruction for the Submarine Force. On a space-available basis, Marine Corps, Coast Guard and Army personnel are also given scuba training, along with selected law enforcement personnel.

The tank and staff have the capability of training 8,500 individuals in submarine escape each year. The instruction staff is made up of two diving officers, one master diver, three medical deep-sea diving technicians, and 23 qualified divers. Each must undergo an arduous qualification period after reporting for duty. It takes an average of six months for a diver to become qualified as an instructor in everything from systems and classroom instruction, to actual water station practice. The diving at the escape tank is unique in that the majority of dives made are breath-hold dives at depths of 25 to 50 feet.

The escape tank maintains two recompression chambers: a double-lock aluminium and triple-lock steel chamber. Their primary function is to perform standard pressure testing for Submarine School students, conduct oxygen tolerance tests for diving candidates and hyperbaric treatment for local diving operations and escape training. The chambers also constitute the primary treatment facility for diving casualties in the New England area. The escape training tank is supported actively by doctors from the Naval Submarine Medical Research Laboratory and maintains liaison with the National Guard, Army, Air-Sea Rescue and State law enforcement agencies in the event that evacuation or treatment of diving casualties is required. This arrangement provides patients with a specialized staff of diving medical officers, along with the complete support of the Naval Submarine Medical Center and its hyperbaric facilities.

The history of the escape tank has not been all smooth sailing. In 1969, the elevator shaft experienced a fire that required the combined efforts of the submarine base and municipal fire departments to extinguish. In 1977, the tank was given its first major overhaul, a task requiring 13 months to complete. During this period, the 135 foot tower, empty and acting like a gigantic sail, was threatened by adverse weather and extremely high gusts of wind. However, all turned out well, and as a final step of the overhaul, insulation and siding were added to the side of the tank to promote.

The escape training tank officially started training students again in July 1978, but only after a thorough instructor training period. Just six hours after receipt of formal systems certification, the staff commenced hyperbaric treatment on a civilian diving casualty. The tank has been in full operation ever since.

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OPERATION PANTYHOSE continued from page 41

For the actual experiment, we locked four volunteers (one female) in the inner lock of the Draeger chamber, with 3000-litre volume, supplied them with an O_2 monitor and a batch of Draeger CO_2 sniffer tubes, and left it up to the pantyhose array to do its bit. To provide for metabolic O_2 requirements, I maintained a constant flow of 2.5 litres per minute of oxygen, which perfectly kept their atmosphere at 21 percent throughout the procedure. Both CO_2 and O_2 levels were determined inside the chamber at 15 minute intervals, and recorded outside, while I maintained more or less constant visual and voice contact with our subjects.

As you might guess, Morgan Wells and I were a bit edgy at first, since the CO_2 levels in this situation could be expected to rise at a rate of 0.82% every fifteen minutes, which gives little leeway. Still, we had plenty of safeguards, so we started the show on time.

Both Morgan and I were a little stunned when the first 15 minutes reading came out at a fat 1.5 percent, and rose quickly thereafter to 2.25 percent. Still, we had some faith in the system, and stuck to our guns. Sure enough, as chamber humidity commenced to rise, the galloping slope simmered down, and after almost three hours stayed steady between 2.75 and 3.0 percent. By this time, we had already designed the Mark II pantyhose scrubber, capable of 75% efficiency, so we called the game and released our volunteers, none the worse for the experience. Tomorrow the MK II will be made up, sealed in plastic bags, and duly installed in the PTC.

Improvised, and at-the-scene experimental work is fascinating. I find it instills a sense of confidence in the aquanauts as well.

<u>DECOMPRESSION SICKNESS and DEEP AIR DIVING</u>

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(This paper is reprinted by kind permission of the Editor of FACEPLATE, the quarterly publication by the US Navy Supervisor of Diving).

NSMRL Researchers show that the occurrence of decompression among US Navy Divers making deep air dives is extremely low, but that when it occurs, it is probably caused by individual differences in susceptibility rather than by pushing the decompression table limits.

The overall incidence rate of decompression sickness among US Navy divers is consistently well below one-tenth of one percent, a figure which is among the lowest in any diving organization in the world. This very low incidence rate attests not only to the safety of the Navy's decompression schedules but also to the manner in which diving operations are conducted in the Fleet.

However, decompression sickness casualties do occur, and we have the responsibility for examining such accidents in order to determine the possible explanations for them and to devise methods to prevent similar accidents in the future.

The vast majority of Navy dives (over 97 percent) utilize air as the breathing medium and are conducted at relatively shallow depths. Approximately 97 per cent of all air dives are to depths shallower than 150 feet of sea water, gauge (fswg). By contrast the majority of decompression sickness casualties occur in deeper dives. If air dives to 150 fswg and deeper are compared to air dives shallower than 150 fswg, the incidence of decompression sickness in the deeper dives is more than ten times that seen in the shallower dives.

Such a finding probably fails to surprise Navy divers. They know (sometimes from personal experience) that deeper dives are generally more dangerous than shallow dives. They also know the importance of selecting the correct decompression schedule. The Navy Diving Manual Section 7.4.2 addresses schedule selection by stating:

"... As assurance that the selected decompression schedule is always conservative – (A) always select the schedule depth to be equal to or the next depth greater than the actual depth to which the dive was conducted, and (B) always select the schedule bottom time to be equal to or the next longer bottom time than the actual bottom time of the dive ..."

The manual goes further by stating;

"NEVER ATTEMPT TO INTERPOLATE BETWEEN DECOMPRESSION SCHEDULES. If the diver was exceptionally cold during the dive, or if his work load was relatively strenuous, the next longer decompression schedule than the one he would normally follow should be selected ..."

This suggests that if there is any question (for example: cold water, heavy work load), the next longer schedule should be chosen.

Navy divers are actually taught to be even more conservative. The procedure taught at the Naval School, Diving and Salvage, is as follows:

If the dive is within 2 feet or 2 minutes of the appropriate schedule, the next deeper and/or longer schedule should be used.

In other words, don't "push the tables". This procedure was recently emphasized in FACEPLATE (see "The Old Master" column, Winter 1976), and allows for depth gauge inaccuracies and so forth. Coming very close to table limits is thought to increase the likelihood of decompression sickness, while dropping to the next deeper and/or longer schedule is believed to add a measure of safety for the diver. Closely related is the belief that most dives that result in decompression sickness are those which do "push the tables."

6,600 Dives Analyzed

During other work involving decompression principles, we became interested in whether or not there is any relationship between "pushing the tables" and the development of decompression sickness.

We obtained data for air dives logged from 1971 through 1975. This information was supplied by the Naval Safety Center and consisted of selected items found on the OPNAV 9940/1 forms ("Diving Log-Combined Accident/Injury Report). Because the majority of decompression sickness casualties occur in deeper dives, we decided to look at all air dives that were decompressed on the 150/10 schedule or more (that is, 150 fswg or greater for 10 or more minutes). A total of 6,600 such dives were logged during the 5-year period studied.

By comparing the actual depth and bottom time of the dive to those of the decompression schedule used, we were able to classify a dive into one of three categories:

1. Under Schedule Limits

   The actual depth was 3 or more feet shallower than the schedule and the actual bottom time was 3 or more minutes less than allowed by the schedule. (Example: Dive 146 feet for 17 minutes. Schedule 150/20 used.)

2. Near Schedule Limits

   a. 2 or 2 - Either the actual depth was within 2 feet of the schedule depth, or the actual *bottom time was within 2 minutes* of that allowed by the schedule. (Example: Dive 146 feet for 18 minutes, or for 20 minutes. Schedule 150/20 used.)
   b. 2 and 2 - The actual *depth was within 2 feet* of the schedule depth *and* the actual *bottom time was within 2 minutes* of what the table allows. (Example: Dive 149 feet for 18 minutes, or 150 feet for 20 minutes. Schedule 150/20 used.)

3. Exceeded Schedule Limits

   Either the actual depth or the actual bottom time exceeded the depth/ time limits of the schedule. In other words, inadequate decompression was given. (Example: Dive 149 feet for 23 minutes. Schedule 150/20 used.)

- Less than 20 percent appear to have followed the NSDS recommendation to use deeper/longer tables if close to the limits (Category 1).
- Over 80 percent of these deep air dives, which are known to be more dangerous, were not decompressed on a deeper/longer schedule even though they were very close to allowable depths and/or times (Category 2a + 2b).

- Over 1 percent of deep air dives received inadequate decompression (Category 3).

The data columns 2 and 3 of the table show that the percentage of decompression sickness casualties in each category (under, near, and exceeding the limits) is virtually identical to the percentage of the number of dives that were made in that category, and there is no statistically significant difference between the two. (For any statistics buffs out there: Yates corrected chi square = 0.255, df=3, p 0.95)

Column 3 shows, in addition, that the decompression sickness rate remains nearly the same across all categories. And so it is true that most cases of decompression sickness occur in dives that are approaching the table limits. But that would be expected, because most dives approach table limits. In addition, the casualties appear to be independent of the “2 or 2” rule.

What this may mean is that the Navy schedules work very well when used correctly, and that most of the time decompression sickness casualties may be related to factors other than the dive/decompression profile itself. We already have scientific evidence that some divers are more susceptible to decompression sickness than others (another example of science “discovering” what field personnel already knew). These differences in susceptibility are loosely termed individual variation, and could possibly be related to factors such as age, physical condition, anatomical patterns of small blood vessels, or sensitivity of the body’s chemistry to stress.

At any rate, since the data indicate that the rate of decompression sickness is nearly the same whether dives are close to table limits or not, the “2 or 2” rule (admittedly unwritten) may not offer as much of a safety margin as thought.

Of course, the analysis does not take into account work load, water temperature, or other dive-related factors, but it is assumed that such factors would balance out between the categories. These conclusions may give dive supervisors more leeway in their choice of schedules or at least less anxiety when dives are approaching schedule limits.

Special comment should be made about Category 3. Although no casualties were reported, all 88 of these dives involved actual bottom times in excess of the schedule time (for example, a dive to 150 fswg for 34 minutes that was decompressed on the 150/30 schedule). The average excess was 5.08 minutes. In no dives was the recorded dive depth in excess of the schedule depth. It is impossible to determine whether this is a real finding, or whether this represents recording errors - either in filling out the 9940/1 report forms or in transcribing them into the computer format. We suspect that it is a recording problem, especially in view of the fact that no decompression sickness occurred in this category. But, if Fleet divers are actually following such practices, they should discontinue them and follow standard procedures.

T A B L E 1

DEEP AIR DIVES AND DECOMPRESSION SICKNESS CASUALTIES BY CATEGORY

CATEGORY Logged	**Column 1 All Dives** %	**Number** Dives	**Column 2 Dives Leading** to Casualties %	**Number** Logged	**Column 3 Decompression** Sickness **Rate Cases per 1000** %
1. Under Schedule Limits	17.0	1119	19.0	12	10.7
2. Near Schedule Limits					
a. Within 2 min. or 2 ft.	30.7	2028	28.6	18	8.9
b. Within 2 min. or 2 ft.	51.0	3365	52.4	33	9.8
Total Near Limits 2a + 2b	81.7	5393	81.0	51	9.5
3. Exceeded Schedule Limits	1.3	88	0.0	0	*
TOTALS	**100.0**	**6600**	**100.0**	**63**	Overall Decompression Sickness Rate = 9.5 Cases per 1000 Dives.

* The number of dives in Category 3 is not large enough to calculate a meaningful decompression sickness rate.

* * * * * * * * * *

Question: What specific evidence is there that whales descended from land mammals? When did these small terrestrial "whales" colonise the sea? Also, how were whales able to evolve their immense size?

Answer: It is generally believed that mammals evolved from reptiles on land. Among the pieces of evidence for cetaceans are the presence, on various species, of vestigial hind limbs, dentition and certain cranial characteristics typical of early land dwelling carnivores, and foetal hair. Also, the general internal anatomy of cetaceans is similar to that of land mammals.

The oldest fossil that can definitely be identified as being part of a cetacean was found in Egyptian deposits of the Early Eocene (50 to 60 million years ago). Since the animal from which the fossil came had undergone some evolution (it was a cetacean, not a terrestrial mammal), this means that the ancestors of the cetaceans colonized the seas over 60 million year ago. The exact time of their entry into the sea, however, is unknown.

The remote origin of the Cetacea has not been directly established because the fossil links between them and other mammals are missing. The cetacean protein structures, however, indicate that they may have had a common ancestor along with the even-toed ungulates (cattle, sheep and camels, or artiodactyls).

continued on page 67.

IMMERSION HYPOTHERMIA IN SCUBA DIVING

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(This paper is reprinted by kind permission of the Editor, New Zealand Journal of Sports Medicine).

Loss of body heat in a cold environment results not only in physical distress but also in slowing of thought processes, loss of muscle power and, if allowed to continue, eventually in coma and death. To a lesser degree it is an important, but often unrecognised cause of exhaustion and a contributing factor in many diving accidents. Since the thermal conductivity of water is more than twenty times that of air, a naked swimmer will tolerate a much narrower range of ambient temperature during immersion than a man would in an air environment. For many individuals thermal balance cannot be maintained below a water temperature of about 24°C (Beckman, 1965). The use of a diving suit somewhat modifies the response to cold immersion but it can be said that hypothermia in divers is always a real possibility at water temperature below about 18°C. This, then, defines the problem both physically and geographically. As most of New Zealand's waters rarely exceed 20°C, the majority of sports divers in this country will experience "cold water" conditions at some time. For many this is a regular occurrence. In both commercial and military diving there was until comparatively recently, a surprising lack of awareness of immersion hypothermia, cold was simply accepted as one of the rigours of life that a diver put up with. Rawlins (1972) has stated that cold stress probably constitutes the major risk factor in cold water diving operations and suggested that cold may have been a prime factor in the death of one of the Sealab III divers. A similar lack of knowledge can be assumed in sports diving. This brief review, therefore, will cover those aspects of temperature physiology relevant to cold water immersion and describe the effects of hypothermia and its implications for sports divers. Finally, first aid management will be described. For fuller reviews of various aspects the reader is referred to the excellent monograph by Keatinge (1969), and to papers by Benzinger (1969) and Golden (1972).

Physiological Responses to Cold Stress

The vital organs such as the heart and brain function well only within fairly narrowly defined limits. Many mechanisms amongst which the regulation of body temperature is particularly important exist for the maintenance and stability of this internal environment. The heat produced by metabolism is lost from the body by means of conduction, convection, radiation, and evaporation. Expressed in its simplest form the rate of heat loss (H) is proportional to the temperature gradient between the centre of the body (body "core") and the skin (dT) and to the heat conductance of the tissues (C). A functional representation of the thermoregulatory system in response to cold stress is shown in Figure 1. In addition to those mechanisms illustrated, body build and fat content play a vital role in heat conservation. Although in air, heat loss through the respiratory system amounts to 15-25% of the total, in water this contribution becomes relatively very small, except in deep oxyhelium diving, and can be largely ignored.

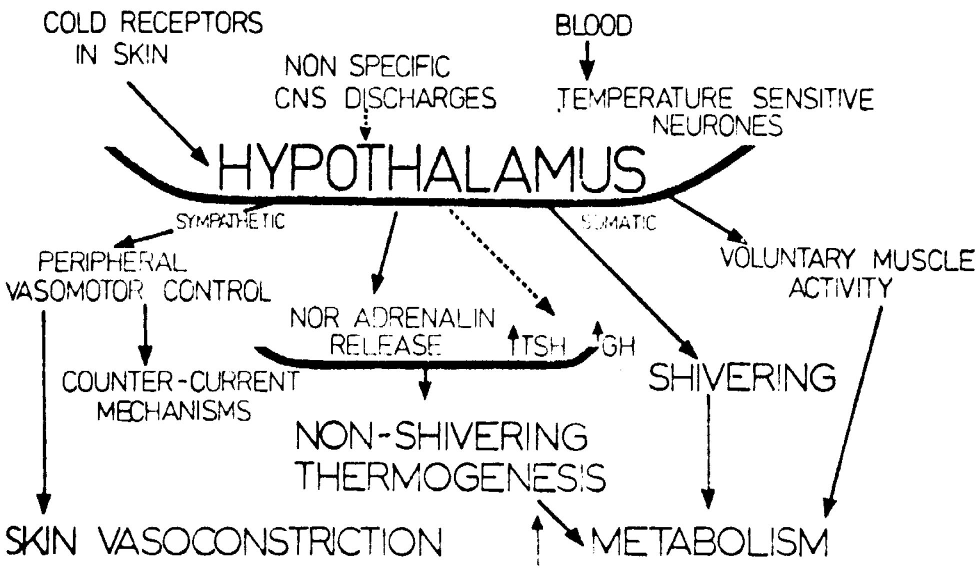

Figure 1. A schematic representation of the thermoregulatory system in response to cold stress. (Central nervous system pathways not shown). The two mechanisms for maintaining heat balance, peripheral vasoconstriction and shivering thermogenesis, important on dry land play a secondary role to subcutaneous fat insulation in determining heat loss during immersion in cold water.

Peripheral Circulation

Functionally the body, in its response to cold stress, may be divided into two parts. A periphery, consisting mainly of the limbs and skin and subcutaneous tissues of the trunk, the extent and temperature of which varies considerably with ambient conditions, and the "core" (which cannot be defined precisely) the temperature of which tends to remain constant. Temperature gradients between the "core" and peripheries always exist even in relatively warm conditions, but in acute cold stress the periphery essentially is "sacrificed" in the attempt to maintain the stability of the "core". This is achieved by peripheral vasoconstriction, involving both skin and muscle blood vessels. The cutaneous vasculature possess a rich sympathetic innervation and is highly reactive, changes in skin circulation occurring primarily in response to the demands of temperature regulation. Peripheral vasoconstriction reduces heat loss by three mechanisms. Firstly, the total blood flow to the limbs falls dramatically (Barcroft and Edholm, 1943). Secondly, the skin possess greater insulation in the presence of vasoconstriction. Thirdly, in reduced flow states there is evidence for an effective counter-current heat exchange mechanism in the deep vessels of the limbs, and this further reduces heat flow (Hong et al., 1969).

Consequent on the peripheral vasoconstriction which occurs immediately upon immersion there is pooling of warm blood centrally. This results in a small but distinct rise in "core" temperature whether measured rectally (Skreslet and Aarlfford, 1968) or via the ear drum (Craig and Dvorak, 1966). This rise is most marked in very cold water when an extremely vigorous vasoconstrictive response occurs. Whilst in air this peripheral vasomotor response is the main effector of heat balance over a wide range of ambient temperatures, in cold water this mechanism is only of temporary benefit and is totally inadequate to maintain central body temperature for any length of time. Figure 2 demonstrates both the initial rise in rectal temperature and the subsequent progressive fall.

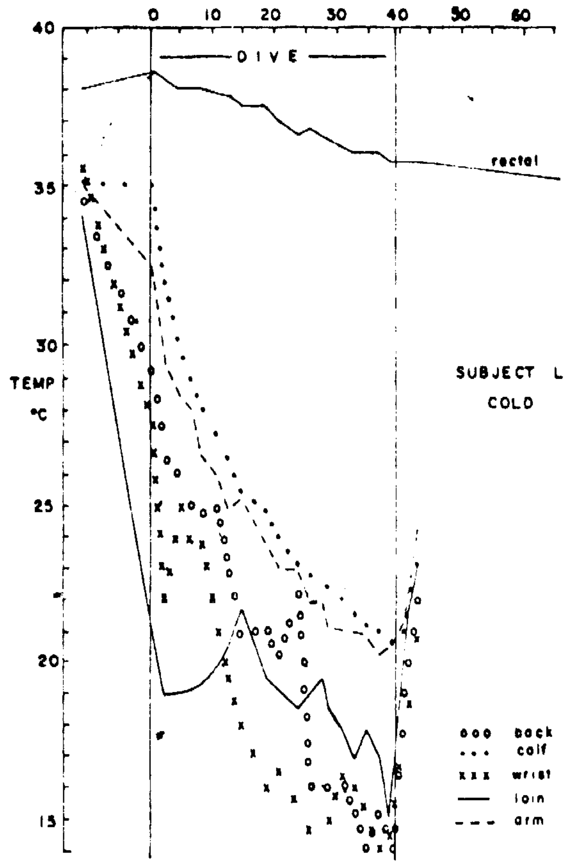

Figure 2. Skin and rectal temperature changes (° Celsius) for a wet-suited diver during a cold water (5°C) dive.

The Role of Sub-cutaneous Fat Insulation.

Most of the heat loss from the body in moderately cold water takes place from the trunk, and the rate of this loss depends upon the amount of subcutaneous fat. Studies of Channel swimmers (Pugh and Edholm, 2955; Pugh et al., 1960) demonstrated most clearly the role of subcutaneous fat in providing effective insulation during immersion. This group of sportsmen possess in general an unusual body build, being thick-set, even frankly obese, with a greater than normal subcutaneous fat layer but a lower than predicted total body fat content. When a channel swimmer and a thin individual were compared immersed at rest in 16° water, rectal temperature dropped in both but sooner and at a faster rate in the thin subject. When exercised in 16°C water, the swimmer's rectal temperature remained constant or rose slightly whereas that of the thin subject fell even more rapidly than it did at rest. Keatinge (1969) showed that the fall in rectal temperature of immersed subjects was inversely proportional to mean skin fold thickness. Upon immersion skin temperature of a naked swimmer rapidly equilibrates with the water (Craig and Dvorak, 1966) whereas in air the body at any given ambient temperature is always greater in water than in air. It is easy to see how, under these conditions, subcutaneous fat determines heat loss. In the fat swimmer heat loss across the trunk is small compared with the thin subject. The increased metabolic heat production of swimming, five to eight times resting levels, is sufficient to compensate for these losses and to maintain “core” temperature. In the thin swimmer the increased convective losses due to water turbulence around the body and the conductive losses due to increased limb muscle blood flow with exercise considerably exceed the increase in heat production and therefore he loses heat more rapidly.

Metabolic Heat Production

The mechanisms described above are concerned with reducing heat loss from the body. Contraction of skeletal muscle, whether in shivering or active exercise, constitutes the body’s only significant means of increasing heat production in response to an acute cold stress. Heat is a problem of metabolism. A highly trained athlete is able to increase metabolic rate to some fifteen times resting levels, whilst shivering will produce a maximum of five or six fold increase. (Resting metabolic heat production is approximately 30kcal per square metre per hour.) The role of non-shivering thermogenesis in man’s response and adaptation to cold is not fully understood. However, there is evidence that divers habituated to Arctic water show progressive adaptation to the cold (Skreslet and Aarlfford, 1968), whilst the Ama divers of Japan and Korea show differences in heat transfer in the limbs (an enhanced counter-current mechanism is proposed) an increased basal metabolic rate and an increased response to sympathomimetric amines when compared with non-diving women from the community (Kang et al., 1963, 1970). Within the context of acute cold immersion these mechanisms probably play little part.

Measurements of “core” temperature

It is worth considering at this stage some of the difficulties of measuring “core” temperature. The body core is a convenient concept but it is by no means uniform in its behaviour and it is only accessible for external measurement at a few sites. Most commonly rectal temperature is used as indicative of core changes, but this method has definite limitations. When the body is cooling rapidly, rectal temperature may fall more slowly than that of the brain or heart and thus be misleading. For instance, Davis (unpublished observations) measured rectal and ear drum temperatures in seven wet-suited divers before and after diving in 9°C water. Rectal temperature fell by 0.75°C whilst ear drum temperature which provides a good indication of brain temperature (Beninger, 1969) fell by 1.8°C. An eighth subject who was a long distance sea swimmer, with the characteristic build described, showed a rise in rectal temperature rose 2.4°C during the dive. As rectal temperature continues at present to be the convenient yardstick for most investigators, “core” and rectal temperature are used synonymously in this paper. A useful alternative is the temperature sensitive radio pill which the subject swallows. Transmission frequency varies with temperature and the signal can be readily picked up with an aerial strapped externally to the abdomen. Again, there are some difficulties in interpretation of gut temperature, and the use of this technique in divers is reviewed by Davis et al. (1975).

The Diving Wet Suit

It is useful to consider three questions at this stage:

1. To what extent does a wet suit modify the physiological response to cold immersion?

2. How does one type of suit compare with another?

3. What are the effects of hypothermia on the diver?

The wet suit is constructed of neoprene rubber 5 to 8 mm thick within which are trapped countless tiny bubbles of nitrogen gas to provide insulation. The suit is not designed to prevent water ingress but rather traps a thin layer between it and the diver’s skin, this layer being rapidly warmed by the body. The net effect of this insulation is produce a water/skin temperature gradient and thus reduce the skin/core gradient (see Figure 2 where skin temperatures are considerably higher than the ambient water temperature of 5°C). However, the wet suit has a number of disadvantages. Beckham (1965) showed that even in a 2.5 cm thick wet suit the average diver was unable to maintain core temperature in 4°C water. Davis, et al. (1975) calculated that the mean heat loss from a resting wet suited diver in 5°C water was approximately 250 kcal per square metre per hour. Webb (1973 using a whole body calorimetry method in the laboratory), quotes 210 kcal per square metre for a forty-five minute dive at 5°C. At a water temperature of 20°C heat loss was approximately 95 kcal per square metre per hour Davis (1975). Even at this water temperature many divers are unable to maintain thermal balance and rectal temperature falls. Consisting as it does of many minute gas bubbles, the wet suit is subject to compression and expansion with changes in ambient pressure. As hydrostatic pressure increases by one atmosphere absolute (1 ATA) for every 10 metres depth of sea water then the suit becomes progressively thinner (Boyle’s Law) and loses its insulative properties at depth. Thus at 30 metres its thickness is reduced about 50% and heat conductance is three times that on the surface (Rawlins, 1972).

Craig and Dvorak (in press) have recently investigated the function of the wet suit during immersion using a whole body calorimetry technique. The suit, by providing a water/skin temperature gradient prevents the initial rapid heat loss seen in the naked swimmer, but does not alter the subsequent steady rate of loss. The study also confirmed that the suit jacket contributed more to reducing heat loss than did the trousers in keeping with the view that the majority of heat loss during cold water immersion is from the trunk. Pilmanis (see next issue) using heat flow discs on wet-suited divers has provided provisional information on the areas of greatest heat loss. These appear to be from the head and neck, upper trunk and shoulder girdle, proximal parts of the arms, the calves during swimming, and the groins and antecubital fossae. This is consistent with current concepts of the mechanisms of heat loss during immersion.

The Diving Dry Suit

As its name implies this type of suit is designed to prevent ingress of water and is made of a strong rubberised material with close-fitting seals at the neck and wrists. Boots are incorporated and most current models are single-piece designs. Suitable clothing is worn beneath to trap a layer of air between suit and skin to provide insulation. To allow for the compression of this air with increasing depth, modern suits are fitted with an inflation device to maintain the gas volume within the suit more-or-less constant. Its efficiency, therefore, deteriorates little with depth. The dry dry suit (or constant volume suit) provides better cold water insulation than does a wet suit as evinced by rectal temperature measurements. Davis (unpublished observations) found that rectal temperature in eight divers fell during a thirty minute 5°C dive by 1.2°C wearing wet suits, but only by 0.5°C wearing constant volume dry suits. Despite this advantage, the lack of convenience, loss of mobility, and considerably higher price compared with a wet suit has limited the constant volume suit's popularity in sport diving but they are used widely in commercial and research diving. In addition, insulation is seriously impaired by leaks tears, and diuresis.

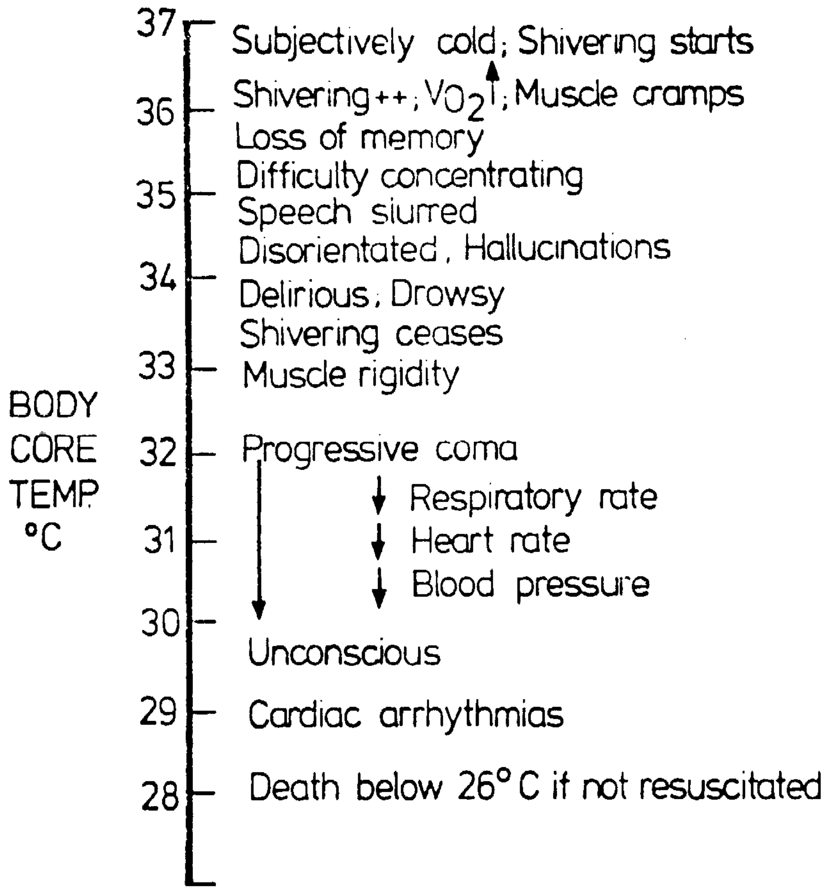

Figure 3 The general effects on man of progressive hypothermia.

The Effects of Hypothermia on the Diver

The general effects of hypothermia are summarised in Figure 3. These are often subtle in onset and pass unrecognised for what they are. It is, therefore, worthwhile attempting to define safe limits in diving practice, and to elaborate on the results of moderate degrees of hypothermia. It is commonsense that in diving any situation is dangerous that results in difficulties in concentration, disorientation and impaired judgment. Thus, a core temperature of 35°C can be taken as an absolute lower limit beyond which the safety of the diver and his companion will be very seriously in question. Where the rate of heat loss is rapid a diver may become prostrated by the cold long before his rectal temperature reaches 35°C. Of fifteen subjects in a cold water performance experiment (Davis, 1975) two had to be removed from the water in serious distress, before completing their 5°C dives. Both were shivering uncontrollably, breathing rapidly, exhibiting slurred speech, and exhibiting repetition of ideas and inadequate response to questioning.

In one, rectal temperature fell by 2.7°C (Figure 2) to 35.7°C and in the other by 2.2°C to 36.8°C. Several other divers exhibited much less distress with lower end-of-dive rectal temperatures, but in every case the drop in temperature was less than 2°C over approximately the same length of time (40 minutes). The more severe the cold immersion the more rapidly will brain temperature fall and the less reliably will the single measurement of rectal temperature reflect this change. Despite this, a strong case can be argued for the continuous monitoring of body temperature during extensive cold water diving programmes in the interest of safety. The Canadian Navy and the Canadian Arctic diving research programmes have both adopted just such an approach using the radio pill.

The "After-Drop" Following Cold Water Immersion

Rectal temperature continues to fall after exit from the water. This phenomenon, known as the "after-drop" (Keatinge, 1969), is characteristic of acute cold stress, and can be seen in Figure 2 in which it is about 0.5°C. Its extent depends on two factors: (1) the severity of the cold stress, and (2) the effectiveness of efforts at re-warming following immersion (see below). In extreme cases it may reach 3°C. Failure to recognise this problem has led to fatalities from exposure that could otherwise have been avoided (Pugh, 1966). A number of reports exits in which shipwreck survivors have been taken from the water conscious, only to lapse into coma and die subsequently. Even in optimal re-warming conditions such as active re-warming using a hot water circulation suit, Webb (1973) found that at least one hour was required for complete re-warming following dives to tolerance limits in 5° to 15°C water, and that core temperature continued to fall during the first fifteen minutes of the re-warming phase.

Diver Performance in Cold Water

The subtle effects of moderate hypothermia have been alluded to earlier. As these have such an important bearing on diving safety it is worthwhile to consider them in greater detail. Only a few reports on cold water performance exist in the literature (Bowen, 1968; Stang and Weiner, 1970); Vaughan and Mayor, 1972; Baddeley et al., in press; Davis et al., 1975) and the reader is referred to these for further details. Divers are less efficient at manual tasks underwater, even in optimal conditions, when compared with that on dry land. This has become known as the "immersion" effect. Superimposed on this are other factors such as nitrogen narcosis (Baddeley, 1967), anxiety (Davis et al., 1972) and cold that further impair a diver's abilities. Cold water exposure may influence performance in three ways. First, there is a peripheral effect on the extremities impairing tactile sensitivity and weakening muscle power (Bowen, 1968; Clark, 1961). Second, there is a central effect on the brain as core temperature drops slowing metabolism. Third, there is what has been called a "distraction" effect (Teichner, 1958), that is, the perceived threat of cold exposure may distract attention and interfere with the continuity of performance.

The way in which performance is altered should be different for each of these mechanisms. Peripheral effects on manual skill are dependent on the ambient temperature (Stang and Weiner, 1970) and show progressive impairment with length of exposure. There appears to be a critical temperature at about 15°C above which manual performance is unaffected (Clark 1961). Davis (1975) using a screwplate dexterity test found a slowing of 17% between 20°C and 5°C by Dusek (1957). These results are in keeping with the other reports cited. Central effects on intellectual ability should only show themselves after a variable latent period since the physiological responses outlined earlier tend to prevent core temperature from falling right from the start of exposure. There is scanty evidence for a central effect developing in cold water dives of less than one hour. Only Davis (1975) has shown any correlation between core temperature and performance. A deterioration of 11% in post-dive recognition of words from a list presented underwater occurred between 20°C and 5°C dives and this correlated with the concomitant drop in rectal temperature in each diver. The distraction effect, on the other hand, should make itself apparent from the start of cold water exposure, impairing performance at a stage when body temperatures have not yet dropped to any extent. There is rather more evidence for this hypothesis from both the studies of Baddeley et al. (in press) and Davis et al. (1975). The impairment of intellectual performance using such tests as simple arithmetic, logical reasoning, and verbal memory appears from the start of cold exposure. In at least one test - simple arithmetic - subjects appeared, in fact, to be at their worst at the beginning of a cold (5°C) dive (Davis et al., 1975).

In practice divers often have to commit to memory in-dive information which is then processed at a dive de-briefing. The resulting loss of data is considerable. Hemmings (1972) found it essential to adopt a diver-to-surface radio communication system with tapes of in-dive reports during fish behaviour studies in the North Sea. He compared tape transcripts with de-briefing reports and found the latter grossly deficient and inaccurate. This situation was mimicked in the above two studies using word lists or prose passages presented underwater for subsequent recall post-dive. In one study the overall deterioration in word recall from dry land to 5°C water was over 70% (including a 48% immersion effect) and in the other 30% from 20°C to 5°C water. This deterioration of memory in cold water is probably a state-dependent effect, that is, recall is optimal when it occurs in the same environment as the original learning process. This context-dependent hypothesis has recently been confirmed by Godden and Baddeley (in press).

First Aid Care for Acute Hypothermia

The treatment of hypothermia can be a complex problem particularly following prolonged exposure or where it is complicated by near-drowning. Only the important aspects of first aid care will be reviewed here, and the reader is referred to Golden (1972) for a thorough pathophysiological review of the subject. Fortunately, in diving one is dealing mostly with acute cases of a few hours' duration at the most, and for these simple and vigorous methods are the most effective.

(1) The first priority is to remove the victim from the water as quickly as possible.

(2) Determine the state of the respiratory and circulatory systems and perform cardio-pulmonary resuscitation (CPR) as required.

(3) Every attempt should be made to reduce further heat loss once out of the water by getting the victim under cover and especially out of the wind. This can be achieved even in small open boats by wrapping him in a tarpaulin, polythene sheet or bag, sails, etc. Remove diving suit or wet clothes and dress in dry clothing as soon as possible. These steps place the subject in a neutral environment and allow rewarming of the patient's metabolism to proceed slowly.

(4) Where facilities are available the most effective method of rewarming

is immersion of the trunk in a hot bath (40-42°C) with the limbs out of the water. This is aimed at re-warming the core as quickly as possible, while slowing down the re-opening of the peripheral circulation. Conversely warming the body surface, for example with hot water bottles, etc., should not be used as it is relatively ineffective in getting heat into the core but encourages vasodilatation. The latter results in an increased heat loss exaggerating the "after-drop" phase and also allows cold acidotic blood from the peripheries to return to the core leading to circulatory collapse, with cardiac dysrrhythmias including ventricular fibrillation.

(5) Hot sweet drinks can only be recommended if the diver is fully alert and responsive. If there are any signs of drowsiness or confusion then fluids (and food) should be withheld because of the risks of vomiting and aspiration into the lungs. Alcohol should not be used as it increases the risk of vomiting and promotes peripheral vasodilatation.

Practical Implications for Diving

(1) In cold water diving, wet suits provide inadequate thermal protection for the diver. A fall in core temperature to 35°C or by more than 2°C is dangerous and even smaller decreases will have some influence on diving safety as the cold diver is liable to panic and exhaustion.

(2) Severe cold stress results in a marked increase in metabolic rate with a raised oxygen consumption and hence more rapid use of air supplies.

(3) Manual dexterity is seriously impaired and this may make even routine procedures difficult and may limit the diver's ability to respond rapidly to an emergency situation.

(4) There is evidence that judgment is impaired from the start of cold water exposure and that the diver's general mental faculties are slowed.

(5) Memory for events underwater is grossly impaired in cold conditions, and this will seriously limit the value of observation and inspection work, unless in-dive records are made. The concomitant impairment in manual skills make writing difficult and therefore in-dive tape recording or diver-to-surface communications are the only effective methods available.

(6) All divers and physicians should be aware of the occurrence of the "after-drop" and must appreciate the safety implications of returning a cold diver to the water without fully rewarming in the interval.

(7) The first aid care of accidental hypothermia should be taught in all diver training courses.

Acknowledgments

I wish to thank Dr Rosemary Ford for her assistance with the text, and Mrs Donna Anderson for preparing the figures.

Drugs and Diving

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There is a remarkable lack of information on the subject of drugs and depths that are associated with sport scuba diving. This, of course, is quite a serious situation, because although the physiological stresses that a sport scuba diver is subjected to, are a lot less than that inflicted on a deep commercial diver, there are:

(1) More sports divers than commercial;

(2) There are likely to be a considerable number of people with conditions which require drugs to control, who want to go sport diving;

(3) There are likely to be amongst sport divers, a significant number of these crazy people who abuse either legal or illegal drugs;

(4) In both categories - commercial and sports - there are people who smoke, and there is no doubt that this must be counted as a drug.

Drugs have become an integral part of modern day life, both in the medicinal sense, and as a source of social problem. Diver training programs as a rule reject the use of pharmacological agents in any form while diving, but in spite of these warnings, many divers do take drugs routinely. The number of scuba deaths worldwide, is increasing. how many of these accidental deaths are related to drug consumption is not known, but there is no doubt that in many cases there is some involvement in this direction. When discussing the effects of drugs on a diver in a meaningful way, it is necessary to know something about the physiological state of the body. Placing a person in an underwater environment, produces a completely new set of variables each of which can be expected to have physiological effect of is own which may be additive or subtractive to each other, and to the pharmacological effect of whatever drug or drugs that may be circulating in the individual at that time.

There are two major effects on the body in this situation:

(1) Hydrostatic Pressure - Straight hydrostatic pressure in itself can produce considerable biological effects. To quote a few albeit extreme examples, enzymes, viruses and toxins can become inactivated about 1,000 atmospheres (ATM). The contractile properties of muscles become rigid and stiff. The viscosity of blood and the dissociation of electrolytes are increased, surface tension is decreased, pH is decreased and many others. Most of these are measurable only at pressures far higher than a diver is likely to encounter, but the subjective sensations and the psychological performance of a diver are so sensitive and involve so many complicated reactions that any slight abnormality may have some relevance (MacDonald, 1975).

(2) Pressure - Gas Interaction. The effects of pressure become much more relevant for a diver when they involve interaction with gases in the breathing mixture. This involves Dalton’s Law and Henry’s Law and their effect on the amount of gases dissolved in solution. When the partial pressure of certain gases becomes sufficiently increased, serious

disorders may occur. I quote such obvious ones as oxygen toxicity, nitrogen narcosis and carbon dioxide poisoning. There is great variation in the sensitivity of individuals to these disorders.

Experiments have shown that changes in hormonal, metabolic, neurological and cardiovascular parameters occur in humans while breathing air at relative shallow depths, and apart from those that are measurably repeatable, there are those which involve the inevitable psychological overlays which are associated with the generalised stress response to increased pressure, and in some cases to anxiety associated with the diving situation. In other words, there is a wide range of changes occurring in the human in the hyperbaric and water environments, which result in a "modified organism". Many of these effects are well known and documented, but others, and by no means least the psychological ones, are not so well understood and are variable. If you then further modify the situation by adding a drug, the pharmacology of which under hyperbaric conditions s~ not predictable, you may well produce a very confused and possibly dangerous situation.

The Effects of Drugs on an Organism

The basic effect of drugs on the body differs from that of pressure. With drugs there is no physical change produced in a cell, rather there is a modification of cell function. Most drugs are distributed in the water phase of the blood plasma . They gain access to this usually by swallowing but, of course, may be inhaled, applied to the surface, or injected. They are distributed around the body, the rate depending firstly on the absorption rate and then on blood flow, and then they affect the target organ or organs. Once again the effect is related to the absorption of the drug across the cell membrane, which is a complex process. The rate of elimination is not simple and is dependent on three main factors: metabolism, storage and excretion. These remove the drug from its site and ultimately dispose of it. There are a wide range of variables which can have an effect on all the above. First there are the naturally occurring ones which include age, sex, height, weight and sensitivity or tolerance, all of which lend to any one drug varying in its effect on different individuals. If a drug is then used under hyperbaric conditions, all the modifications of the physiology of the person must then be taken into account. The end result in most circumstances is not predictable. Very little work has been done so far to assess different drugs fortheir efficacy or their relative safety in relation to divers.

Two main classes of evaluation of the effects of a drug in these circumstances really need to be done, that is Toxicological Evaluation which is the direct effect on the working off the cell and BehaviouraI Evaluation or the effect on the whole body.

(1) Toxicological Evaluation. Most of the work done in this field so far has been at pressures of 19-20 ATM (ie. around 180 metres depth), and helium has been substituted for nitrogen in the breathing mixture. Much to the surprise of the investigators, the toxic and pharmacological effects of, for example, morphine, at 19 ATM were not substantially altered from those at the surface although there is some evidence that the rate of metabolism may have increased (Tofano, 1975). Also, the LD 50 (ie. the lethal dose (LD) where 50% of subjects die following administration) of barbiturates and ethyl alcohol were not substantially different. All of the above, of

course, has been done using laboratory animals so it is not always directly applicable to humans. It has all been applied to the deeper environment where helium is needed and there appears to have been very little work done in relation to the 2-7 ATM range with air as the breathing mixture. An interesting fact at this stage can be related. During the 2 year period 1972-73, 99% of all recorded dives were by the US Navy (over 125,000) all to depths of 60 metres or less, breathing air. Less than 0.1% were made to 180 metres or more. In view of this, and of the incredible numbers of sports divers in existence, the lack of work into the shallower depths is most disappointing.

(2) Behavioural Evaluation. This really involves the objective changes in behaviour and subjective changes in mood and attitudes. In other words, the changes in behaviour that would be evident to a trained observer, and the changes in mood and attitudes that the person themselves feel in the conditions prevailing. Both are usually combined, and provide potentially lethal situations for a diver. Examples involve the sedative effects of drugs combined with any neuromuscular lack of control brought about by the drug and the effect of pressure. That the diver may also have a feeling of euphoria and the lack of caution in these circumstances is well known to us all. More work has certainly been done in this field as opposed to the toxicological field, but mainly with animals. The technique of this is as follows: it is known that complex behavioural patterns can be developed both in laboratory conditions and under hyperbaric conditions. This baseline must be established and then dose-response curves are obtained with some surprising results. The results of these studies show that the behavioural effects of drugs do change even with depths as low as 50 feet, but that the effects are not predictable when compared with their effects at the surface. Some are potentiated and some antagonised; that is for one compound the behavioural effect of a 1.0 mgm dose at depth may be the same as a 10 mgm dose on the surface, or with another compound the effect of 1.0 mgm at depth may be the same as a 0.1 mgm dose on the surface. However, the most important feature to be borne in mind is that the effect at depth is not predictable. All the basic measurements are made on animals and as such may not be directly applicable to humans, but each diver at some stage is going to be faced with the question, “Is it safe for me to dive today?”, in relation to some treatment that he may be receiving, or to make his own individual decision whether to go diving in relation to some drug that he may be abusing.

An indication of the relevant dangers associated with a selection of these drugs will be given, bearing in mind that the information cannot be relied on as being 100% accurate in all circumstances due to lack of reliable information. First is to define what is meant by a drug. The dictionary defines a drug as “any substance used in the composition of medicine; a substance used to stupefy or poison or for self-indulgence”. If this is carried to its logical extreme, it can be taken to mean any foreign substance ingested, inhaled, or applied topically, with the exception, of course, of food, and even food in excess could almost be included in that definition.

To examine the effects of these various substances on the body, a logical way of doing so would be to divide them up into separate categories according to the particular system of the body that they affect. It must also be realised that when the effect of a drug is being considered in relation to its effect in a hyperbaric situation, the condition for which it is being prescribed (if that is the case) must also have a very large effect on the end decision. In other words, to quote an example: if a person goes to a doctor and asks if the digoxin he is taking for his heart condition will be affected by pressure, it is obvious that the most important thing is not the digoxin but the heart condition. There are many such examples where the medical condition is of greater importance than the pharmacological effect of the medication. The best way of classifying the whole subject is to run through a list of the drugs most likely to be encountered, and discuss their effects on the main systems of the body, which are:

(1) Nervous System,
(2) Respiratory System,
(3) Cardiovascular System,
(4) Gastrointestinal System.

One of the most important single systems is the nervous system, and anything which has an effect on this is likely to have far reaching effects on the diver. A list of the more common drugs which can have an effect is almost endless, the more common of which are (1) Alcohol, (2) Narcotics, (3) Hallucinogens, (4) Tranquillisers, (5) Amphetamines, (6) Hypnotics, (7) Barbiturates, (8) Antidepressants, (9) Antiemetics, (10) Antihistamines, (11) Decongestant sprays and tablets, (12) Antiasthmatic treatments, (13) Cardiac drugs, (14) Tobacco.

ALCOHOL

This is probably the most commonly used drug associated with diving. How many of us have been out on a diving expedition, particularly on a weekend trip, where there has been a really good party one night and there is a dive the next morning when quite a few people plunge into the water nursing anything from a mild to a severe hangover. Ethyl alcohol is a cerebral depressant. Contrary to popular opinion, it does not stimulate the person who consumes it, but rather leads to this impression, by depressing inhibiting factors in a personality. Some ordinarily inhibited people, under the influence of alcohol feel freed of social restraints and believe themselves to be stimulated. Alcohol being a cerebral depressant has a directly additive effect with nitrogen narcosis which may be quite unpredictable. To return to the hypothetic case of the party the night before a dive, assuming that it has been reached at 2-3 am. The dive goes on at 9 am. It is not generally realised that alcohol falls only slowly (15-18 mgm/hour), so at 9 am it is quite likely that our partygoing diver is still over the limit for driving a car, which in diving terms is nothing short of suicidal. American records state that a significant percentage of diving deaths have some alcohol associated with them (Dietz). Alcohol also has other side effects. It causes peripheral vasodilation or opening up of the circulation of the skin, leading to an increased loss of heat from the body, with the end result of potentiating hypothermia. It also causes a reduction in the surface tension of the serum and will encourage the formation of bubbles and decompression sickness. In other words, alcohol is absolutely contraindicated associated with diving.

NARCOTICS (Morphine, Pethidine, Heroin, Methadone)

Usually, when associated with diving, these will have been the subject of abuse, although methadone may have been legally prescribed as blockade therapy in the treatment of narcotic addiction. Very little work has been done on the effects of hyperbaria related to these drugs, and the only references relate to rats and mice. There is some evidence related to the toxicological effects in that in rats the metabolism of narcotics may be stimulated but no behavioural studies appear to have been published in the literature. However, it would be a foolish person who would go diving while under the influence of a narcotic drug with its known depressive effects on the cerebral cortex and brain regulatory centres, in particular the respiratory centre.

HALLUCINOGENS

There has been no work published in relation to the effects of LSD and hyperbaria. Probably, of more practical importance is the effect of pressure in relation to marijuana. This hallucinogen is in common, although illegal, use. The main psycho-active ingredient is tetrahydrocannabinol (THC) It causes perceptual distortions to those using it. It has been shown that the effect of pressure reverses the behavioural toxicity of THC. In other words, the deeper a person goes, the less he is affected by Marijuana (Walsh, 1977).

It is obviously ridiculous to suggest that this is an open invitation to all pot smokers to take up diving, because the effects are reduced only, and there are still the dangers of diving to consider. In addition, one other fact has surfaced related to marijuana in that it causes dilation of the peripheral vasculature with its associated increased heat loss and may contribute to the development of hypothermia.

TRANQUILLISERS

This subject has been a little more thoroughly researched but by no means fully. Some work has been done on Chlordiazepoxide (Librium) which is a minor tranquilliser, and on chlorpromazine (Largactil), a major tranquilliser. There has been shown to be a consistent reduction in response rates in rats when the drug is combined with depth. This study was done with rats trained to depress a lever for food rewards and is shown in the graph with two different animals who were tested at surface level with the drug and at a depth of 250 feet breathing air. A steadily decreasing response rate is shown with increasing dose of drug in this case Librium (Thomas, 1973).

AMPHETAMINE (ie. Speed or Benzedrine):

Originally it was thought that Amphetamine, a cerebral stimulant, might reverse the narcosing effect of nitrogen at depth. Much to the surprise of investigators, the results show there was an increase in behavioural dysfunction when a subject was placed under increased pressure. In other words, amphetamines do not reverse the narcosing effects of nitrogen, but that they increase it (Thomas, 1973).

HYPNOTICS AND BARBITURATES

Hypnotics are sleeping tablets of various types, the most commonly used one today being nitrazepam (Mogadon). Others which are used, although not so commonly these days, are the various barbiturate hypnotics, and a smaller number of others which are not related to either of the above two types. The only one which appears to be described in the literature is one of the barbiturates, pentrarbarbital (Hart, 1974) and this has been shown to increase significantly the awakening time of mice, but not of cats, guinea pigs or rats. No human studies are available. Nitrazepam is chemically similar to chlordiazepoxide and could probably be assumed to have similar properties. There is no description available for any other hypnotics. In general, however, the hypnotics are central nervous system depressants and probably could be expected to act additionally with narcosis and cause a greater brain depressive effect.

ANTIDEPRESSANTS

There appears to be no literature describing the effects of hyperbaric on these compounds. These drugs act by altering the amounts of adrenalin like substances in the brain, and their pharmacology is complex, and the relation of this to the hyperbaric situation is not easy to predict. However, some of them have a side effect of sedation and this could well act to compound nitrogen narcosis. One also wonders at the advisability of allowing a potentially or actually depressed person to dive. Each case would need to be thoroughly assessed by a competent medical adviser.

ANTIEMETICS AND ANTIHISTAMINES

Antiemetics are the anti seasickness pills of which the numbers and varieties are legion. They are chemically, in most cases, closely related to the antihistamines or antiallergy pills and so can be included in the same description. Once again, the only published work has been with test animals (Walsh, 1977), and it has been found that there is no loss of performance with pressures up to 7 atmospheres. The test substances were Dramamine and Benadryl. However, these are not the only drugs of this type available and any diver who takes either an antiemetic or an antihistamine and finds himself sedated, would be unwise to entertain thoughts of diving to any significant depth. Some of these drugs, however, do have a peripheral vasodilatory effect and as such may contribute to the production of hypothermia.

DECONGESTANT TABLETS AND SPRAYS

One of the most commonly used decongestant tablets is pseudo-ephedrine. This in its trade name appears as Sudomyl. It is also available in other mixtures where it is combined with an anti-histamine, the commonly used one in New Zealand being Actifed. This can, at times, have a sedating effect and should be treated with some caution initially, until the diver is familiar with it. There is another similar mixed tablet called Eskornade and the same advice should apply here. Returning to pseudo-ephedrine in its “pure” state. Recent tests in the USA (Walsh, 1977) have shown that there is no performance loss in rats taking therapeutic doses of this drug down as far as 7 ATM. The toxicological side effects are not discussed. Decongestant sprays are quite commonly used, and serve a very useful function, but are subject to certain pitfalls which a diver should be aware of and note to avoid running into trouble. They can be used to decongest noses and thus decongest the lower ends of the Eustachian tubes. The great danger with preparations of this type is the fact that they may wear off while underwater and a reverse block condition arise. To help avoid this, only the long acting types should be used, and these themselves should be used fairly close to the time of diving. The common long acting ones available in New Zealand are Drixine or Otrivine. Other short acting ones are not advised. A note of caution should be sounded here. These types of products should be used only when there is a minor abnormality to be corrected. They should never be used to enable a person to go diving who is suffering from a full flown attack of sinusitis or a cold. There appears to be no research on the side effects, if any, of these decongestants.

ANTI-ASTHMATIC TREATMENTS

There was no reference in the literature to the study of the effects of anti-asthmatic drugs. This is probably because no person who suffers from asthma would ever be considered as a candidate for a professional diver. Practical facts must be faced and there are a lot of people who suffer from asthma who go diving. One of the main risks for these people is that of air entrapment either by bronchial spasm or mucous plugs, with the resultant danger of embolism. Medication can reverse the effects of asthma in some cases, but should never be used to do so for the purpose of a dive. In other words, a person with active asthma should never go diving (Kindwall, 1977) .

CARDIAC DRUGS

These comprise the drugs which affect the heart. There is little mention of them once again in the literature. The reason being that sufferers from cardiac disease do not qualify as professional divers. Kindwall (1977) states in an article on the subject of diving and heart disease that "he must have no angina, arrhythmia or heart failure and must have a normal exercise tolerance. A stress ECG should be normal." All this would exclude a person who was using this type of drug.

SMOKING

No review of drugs and diving would be complete without a mention of smoking which, despite the objections of chronic smokers, must be considered as a drug of abuse. The ordinary smoker is faced by the dangers of heart disease, lung disease, and peripheral vascular disease, that this damage to and narrowing of the arteries in the extremities. It is now suggested by some American authorities (Triton, 1975) that divers who smoke face extra hazards. The nicotine and tars in tobacco smoke are potent irritants of the respiratory tract and cause considerable mucus production and bronchial spasm. It has also been shown that smokers are particularly liable to develop small airways obstruction even after minor infection such as the common cold, and this effect can last for over one month in some cases. The result of the abovementioned can lead, as with asthma, to an entrapment with the corresponding dangers of pulmonary barotrauma.

Also, it has been shown that a 30 cigarette/day man has some 15% of the haemoglobin in his blood occupied by carbon monoxide to form carboxyhaemoglobin which blocks the haemoglobin-oxygen transport mechanism. This is not usually evident in ordinary day to day living, but when heavy exercise is undertaken could be quite significant. The comment is made in one article that, "It is amazing that divers will go to considerable lengths to ensure that their breathing air is free from impurities, but will voluntarily pollute their lungs and circulation this way". There are many divers who smoke and dive successfully, but the risk taken by these people must be higher than the non-smokers.

CONCLUSION

This has been a discourse on the relationship of drugs and diving. Mention of the large range of drugs which are used to treat conditions that arise from diving has been avoided, as have also the large number of drugs that have been experimented with, for the purpose of preventing such conditions as decompression sickness and oxygen toxicity. It will be apparent, that many of the drugs which may be used while diving have quite unpredictable side effects, even when these are well known and documented in surface pressure conditions. None of the side effects appear to be of any use to the diver, and most of them appear to be hazardous in some degree at least. The British Sub-Aqua Club Medical Committee has issued the following statement - "The use of sympatho mimetics betablockers, steroids, digoxin, muscle relaxants, antihypertensives, diuretics, and all diabetic drugs are definite contra-indications for diving. Antihistamines and analgesics should be used with caution. If a candidate has been using psychotropic drugs, including tranquillisers, sedatives and hypnotics, he should not dive for at least three months after cessation of therapy, without the consent of the Medical Referee." This indicates the seriousness with which they view drugs associated with diving. This statement may well be too inflexible for some people who will argue for some flexibility in the prohibitions. To a certain degree, this could be agreed with and each case should be individually assessed by a competent authority, and the diver made aware of such limitations as may be necessary for him to be safe. There will, however, always be the total and absolute contra-indications, and with these, without exception, must be included all the drugs of abuse. This paper has concentrated on the types of drug which are liable to be associated with the ordinary diver and his diving. Many of the drugs which will be encountered will have been prescribed for medical conditions, which themselves will be more important in saying whether a person can do diving than the theoretical side effects of a drug. You will note the word "theoretical". This has been used advisedly right throughout as very little work has been done on the interaction of commonly used drugs and hyperbaria, especially in relation to the types of conditions and depths that sports divers, who constitute the vase majority of all divers, will encounter. In the future it is hoped that much more information will be available.

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"WHAT PILLS HAVE YOU GOT FOR SIDE EFFECTS?"

DIVING MEDICAL CONFERENCES

The Diving Medical Centre will be holding the following meetings:

1980 November 15-29th. Diving Medical Seminar held in New Zealand (Bay of Islands - Poor Knights) one week. One week extension for tour of new Zealand or one week in Tonga.

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Information available from Biomedical Marine Services Pty Ltd, 25 Battle Boulevarde, Seaforth, NSW 2092.

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MEDICAL PROBLEMS PEOPLE CAN DIVE WITH

Ronald P Bangasser, NAUI 3909, California

(Reprinted form NAUI News May 1979 by kind permission.)

As an instructor, I'm sure you have been approached by potential students who want to learn to dive, but who have a medical problem marked on their physical form. What do you do? You probably aren't familiar with some or most of the medical terms used on the standard associations' forms. So you tell them to see a doctor and, usually the doctor, knowing little of the effects diving will have on the patient and being cautious, will not clear the student. Now you've contributed to preventing a person from enjoying the underwater environment and you have also lost a student.

Well, then, who should or should not dive? Can everybody dive? There are several definite absolute contra-indications to diving:

1) Persons subject to spontaneous pneumothorax;

2) Persons subject to epileptic seizures or syncopal attacks;

3) Persons with lung cysts; emphysema; or air trapping lesions on chest x-rays;

4) Persons with a ruptured ear drum with a permanent hole;

5) Persons subject to active acute asthma attacks;

6) Persons addicted to drugs of any kind;

7) Persons with brittle diabetes if the individual is or has been subject to insulin shock or diabetic coma;

8) Persons who have had ear surgery with placement of a plastic strut in the air conduction chain.

If a person has any of the above, they should not dive. But most people with medical problems don't fit the categories above. In my experience as a physician in the diving community, as well as a diving instructor, several areas of medical problems often crop up.

A more common problem I am presented with is a person who has a learning disability. There are many different types of learning problems, but I have found this problem rather easy to handle. First, as an instructor, you must sit down, take some time with the student, and find out where their understanding breaks down. Usually the student will know that he will have trouble understanding your notes or understanding your oral teaching or writing down his own notes fast enough. Whatever type of problem they have, you can usually find an easy way to circumvent it. For example, if they have trouble keeping up with notes, give them tapes of your lectures to study at home. Usually, I have found these students very enthusiastic and they do very well, pass the written exam, and make excellent divers. The key to solving the learning disability problem is taking extra time. If you are willing, the rewards are great. A good side effect of teaching a disabled person is that you have a chance

... JUST BEING OLD
IS NOT REASON ENOUGH TO
PREVENT DIVING ...

to assess your teaching ability. It can be a very interesting. My experience includes hypertensive patients, many allergic-type problems, and others, even including a renal transplant patient on several toxic medicines. Probably more important to a person's success or failure in a diving class than the medical problem is their physical condition. If they are prepared for the course, knowing the required physical activity then the student usually succeeds.

Often I will be called concerning the student who has been disqualified from the diving class by a doctor, who says they are "too old" to dive. Sometimes there may be a medical problem related to age that may prevent a person from diving, but just being old is not a reason. Having taught several people in their 60's to dive, I have found they are sometimes better than students half their age. Here again, major reasons for their success were enthusiasm, physical fitness, and an awareness of their limitations. And you, the instructor, are an integral part of each one of those three areas.

Finally, I would like to discuss the problems associated with physical disabilities, including amputees, paraplegics, and cerebral palsy patients. Can these people dive? In this case, the answer is yes they can dive. However, to become successful divers, they will take lots of instructional time and patience, sometimes on a private or semi-private level. Some instructors may not want to tackle this type of student, but in my experience, these students are the most satisfying to teach. In the water, many can overcome most of their on-land problems. They can find a now freedom. It can be truly exciting. Care must be taken here concerning whether these students may receive full certification. Remember, they may be required to save a buddy or get a person who is in trouble back to shore.

There are many individual problems that may come up that aren't possible to specifically discuss here. Usually most people who are interested in diving and have some idea of the energy output needed in this sport, can become certified. Mostly, it comes down to our attitude toward medical problems as instructors. The solution can be found in our interest in the student, expending a little extra encouragement and time. But the pay-off is that these will be some of the best and most grateful students you will ever teach.

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