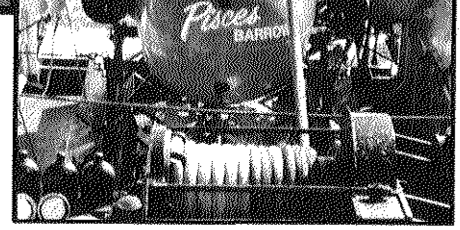
Scientific Diving:
a general code of practice



Edited by
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on behalf of the Scientific Committee of the World Underwater Federation (CMAS)

FLORIDA SEA GRANT COLLEGE PROGRAM
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WORLD UNDERWATER FEDERATION CMAS

Scientific Diving: A General Code of Practice

Cover photos, clockwise from left: Institute of Oceanographic Sciences, Deacon Laboratory; Kalmar Läns Museum, Sweden; Nardo Vicente; N. Flemming; Marine Laboratory, Aberdeen.

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PREFACE

Scientific diving is now one of the most productive scientific techniques of oceanography. It is both complementary and supportive to remote observations, measurements and the collection of data and materials achieved at sea using oceanographic investigations.

From the very beginning of research in the sea, scientists have made efforts to observe personally the marine environment below the surface. Marine biologists, in studying coral reefs and other benthic fauna and flora in shallow water, made some progress through free diving. Others ventured deeper by using cumbersome diving suits which were dependent on life support from the surface. Later, submarines and tethered manned devices were to enter the scene as useful tools for *in situ* observations. However, the real breakthrough came in the mid-1940s with the development of the "Self-Contained Underwater Breathing Apparatus", commonly known as the scuba or aqualung.

Thus equipped, the diver has proved invaluable in support of marine scientific research, and this can be seen in at least two types of activity. First, the study of the upper undersea milieu is more feasible through use of the relatively independent, free-moving diver. Secondly, much of the equipment used in marine research is complex and expensive, and often the safe deployment and recovery of some of that equipment can be or even must be aided by divers.

In 1961, oceanography became a well-recognized activity in Unesco in response to the need for international co-operation in this field as expressed by the scientific community. In Unesco, scientific diving is recognized as a useful oceanographic tool, as well as being invaluable in submarine archaeology and other fields.

The scientific communities in most coastal countries, particularly in the developing world, are studying their coastal marine resources and shallow-water ecosystems. In light of this, Unesco, especially through its Division of Marine Sciences, has undertaken several initiatives to which the professional activity covered by the present volume is relevant. For example, within the framework of its Major Interregional Coastal Marine Project (COMAR), Unesco promotes coastal research and training leading to improved management of the resources and environment of these areas. Also, in collaboration with the International Association for Biological Oceanography (IABO, one of the scientific bodies in the system co-ordinated by the International Council of Scientific Unions), a manual has been produced entitled *Seagrass Research Methods*, Number 9 in the Unesco series Monographs on Oceanographic Methodology (in press). Requests to Unesco from its Member States for assistance in the salvage and restoration of sunken archaeological artefacts and sites may also be mentioned, as may several books and periodical issues on submarine archaeology that have been published by the Organization.

In 1984, the World Underwater Federation (in French: Confédération Mondiale des Activités Subaquatiques, or CMAS), a non-governmental organization with consultative status with Unesco on matters concerning diving, agreed with the Organization to develop a code of practice for scientific diving on the basis of work already being carried out by CMAS. The purpose was to provide advice to divers, particularly as regards their safety, in a variety of working conditions. This collaboration between the Federation and Unesco's Division of Marine Sciences resulted in the present Code of Practice, accomplished thanks to the co-operation of many scientists whose work was co-ordinated by the CMAS Scientific Committee. The names of these contributors are given in the Foreword and Appendix 4. In particular, the present work is a result in large part of the long-term, patient efforts of Dr N.C. Flemming, of the Institute of Oceanographic Sciences Deacon Laboratory, Wormley, UK, and former President of the CMAS Scientific Committee.

The Code of Practice was first distributed in 1988 as Number 53 in the series Unesco Technical Papers in Marine Science under the title "Code of practice for scientific diving: principles for the safe practice of scientific diving in different environments". In its present version, the text is being published in an improved form and will be made more widely available to individual divers. Unesco appreciates the co-operation of CMAS and the Florida Sea Grant Program in bringing this about.

Mrs. A. Roberson carefully checked the text and references and prepared the corrected composition for this version. The typographical enrichment, cover design, artwork and final layout, as well as the printing, were carried out by Ms. S. Rodgers and Mr. J. Potter under the direction of Dr. J. Cato and Mr. J. Humphreys (Florida Sea Grant College Program, University of Florida, USA). Appreciation is expressed to all those who assisted in making this publication available to the international community.

United Nations Educational, Scientific and Cultural Organization

About the editors:

Dr Nicholas Flemming has been using diving methods in marine research since 1957 and has published over 70 scientific papers and technical articles on diving and research results from diving. He was President of the CMAS Scientific Committee from 1975 to 1987; Chairman of the British Sub-Aqua Club from 1978 to 1981; and is now a Vice-President of both CMAS and BSAC. He is presently Secretary of the British Co-ordinating Committee on Marine Science and Technology.

Dr Michael Max took up diving in 1974 to carry geological mapping from the land to near-shore areas while employed by the Geological Survey of Ireland. He was Diving Officer of the Survey for 10 years and Science Officer of the Irish Underwater Council from 1981 to 1985, while being active on the Scientific Committee of CMAS. He has published over 100 scientific papers and reports, of which about 20 contain information gained while diving or concern technical aspects of diving. He is currently a member of the American Academy of Underwater Sciences, and is employed by the Naval Research Laboratory (Washington, DC, USA).

FOREWORD

The World Underwater Federation (Confédération Mondiale des Activités Subaquatiques - CMAS) was formed in 1959 to promote and improve self-contained air diving for sport, exploration and science. It succeeded in establishing the international system of recognized training and equivalence of certificates between countries, to which forty-eight countries are party.

The Scientific Committee of CMAS issues Scientific Diver Qualification Brevets which recognize the status of a diver who is qualified to dive in the course of research whilst employed. Having an internationally recognized scientific diving standard of competence is a distinct advantage for working scientists who wish to travel between laboratories and institutes in different countries.

International scientific diving symposia have been held by CMAS every two or three years since 1970 at which refereed scientific papers are presented on marine geology, biology, archaeology, technology, and diver instrumentation. The Proceedings of these symposia have been published, and those that are still in print are available from the CMAS office.

Scientific research diving is carried out by thousands of professional research workers, graduate students, technicians, and undergraduates around the world, and by some people in commercial employment. Overwhelmingly the technique of diving used is self-contained air (scuba), although mixed gas, surface demand, habitat, and lock-out submersible systems are also used.

National codes of practice for scientific diving have existed in several countries since 1970. These documents differ in their context within national legislation, and regional environment, and hence emphasize or omit different factors. Science is international by nature, and marine science involves frequent co-operation between scientists from many countries. It was therefore logical to consider a Code of Practice for the conduct of scientific diving which would combine the expertise of Diving Officers, Administrators, Legislators, and individual divers, from different parts of the world scientific community.

This Code of Practice further extends the CMAS service to marine scientists by offering a set of guiding principles for the conduct and administration of safe and efficient scientific diving in a variety of environmental and laboratory conditions. The Code is written for informed divers, Diving Officers, Scientific Project Leaders, and senior administrators responsible for diving programmes or safety in institutions. It is largely advisory, and brings to the readers' attention benefits of the experience of other scientists who have worked under the sea, in freshwater, and in a range of artificial conditions.

The CMAS Scientific Committee owes a debt of gratitude to the experienced divers who first suggested this Code, Professor Glen Egstrom of the University of California, Los Angeles, and Dr. Nigel Mathers, then of the Heriot-Watt University, Edinburgh. In 1984 Dr. Michael Max took on the secretarial and administrative responsibility for editing the Code. Initially over 100 potential contributors in 30 countries were contacted. While many of the replies contained substantial sections (for instance Sections 5 and 11), other replies contained more brief comments and suggestions for new material and new contacts. The final list of contributors is contained

in Appendix 4. The CMAS Scientific Committee is extremely grateful to all those people who have searched their knowledge, experience and judgement, to contribute to this Code.

The preliminary draft of this text was reviewed by a meeting of diving officers from different institutions held at Wakulla Springs, Florida, in November, 1986. These divers reviewed the text individually before the meeting, and then as an editorial team seeking consensus. These people deserve special thanks: Dr J. Bozanic (Next Generation Services, Inc., USA); Dudley Crosson (Florida Institute of Technology, USA); David Dinsmore (NOAA National Undersea Research Center, USA); Dr N.C. Flemming (IOS Deacon Laboratory, UK); Michael Lang (Biology Department, San Diego State University, USA); R. Palmer (Department of Geography, University of Bristol, UK); Hans Roverud (University of Bergen, Norway); P. Sharkey (University of Rhode Island, USA); Dr R. Sparks (University of British Columbia, Canada); Dr Gregg Stanton (Florida State University, USA); Dr B. Townsend (Fisheries and Oceans, Canada).

The CMAS Scientific Committee thanks all those people mentioned above who helped to produce this Code and acknowledges the help and advice given by many other people through letters or oral comments. Wherever possible these practical hints and observations have been incorporated into the final text.

The first printing of the Code was very well received, and if this edition is equally successful, it is the intention of CMAS to up-date the text at intervals of a few years to keep it constantly abreast of evolving technical and safety developments.

Recipients and users of this volume are invited to send their name and address to Scientific Committee, CMAS, 47 rue du Commerce, Paris 75015, France, if they wish to receive notice of revisions, reprints, etc. Commentary and suggestions should be sent to the same address.

N. F.
M. M.

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INTRODUCTION

I. Objectives

This Code of Practice is designed to meet the following objectives:

1. To provide guidance on the safe practices in scientific diving, based on information and documents from experts in many countries.
2. To benefit from the specialized experience of scientific divers in many countries, so as to provide the best advice on diving in different, unusual or extreme conditions.
3. To provide the basis for mutual recognition of standards between countries and between institutions, so that scientific divers can move more freely and co-operate more efficiently at an international level.
4. To create an agreed-on voluntary standard of reference on scientific diving practice, thus avoiding the necessity for restrictive legislation to control diving safety.
5. To provide a bibliography and references to accepted codes and manuals, address lists and other reference sources for scientists wishing to establish a scientific diving program.
6. To provide guidance concerning legislation in those countries which have laws controlling scientific diving.
7. To provide an ethical basis for establishing diving procedures in conditions where diving has never been practiced before.
8. To strengthen the international community of scientific divers, and to support a general approach to maintaining safety which can evolve as technology evolves, without the rigidity of a mandatory legal document.

II. Origins of this Code

The Scientific Committee of the World Underwater Federation (CMAS) held a meeting in Stockholm in 1977 to discuss the effects of national diving safety legislation on scientific diving in different countries. Examples of legislation and codes of practice were collected, and advice was sought from many experts. Later in 1977, during the General Assembly of CMAS in Brisbane, Australia, a discussion meeting on codes of practice voted unanimously in favour of the development of an international Code of Practice, which would serve as general guidance of a non-legislative, non-mandatory nature, and would be suitable for use in all countries.

At the Scientific Symposium of CMAS in Edinburgh, Scotland, UK, in 1980, a start was made on drafting the contents of such a Code. In 1982, at the Joint Oceanographic Assembly organized by the Scientific Committee for Oceanic Research (SCOR), in Halifax, Canada, the subject was discussed with Dr. Selim Morcos of Unesco (Division of Marine Sciences). In 1983 CMAS made application to Unesco (Division of Marine Sciences) supported by SCOR, for financial support to produce the Code of Practice. Approval was granted.

A code of practice operates at a level between legislative rules and a diving manual. Legislation is usually written by persons trained in law, tends to be brief, very factual, mandatory, to concentrate on forbidding undesirable actions and to be deliberately general so as not to depend upon rapid changes in technology. A change in legislation usually takes several years. On the other hand, a diving manual is written by persons with experience of diving, is extremely technical, expounds in detail upon the construction and use of equipment, contains great detail upon training methods and techniques and may be revised at short intervals. A diving manual also tends to discuss only those diving methods which are relevant in the geographical area to which it applies.

This Code of Practice bridges the gap between these two kinds of documents, by giving discretionary advice based on the wide experience of many experts. It seeks to give positive information on techniques which are useful, rather than only to forbid. Where manuals and codes already exist giving detailed professional information, the Code provides references and a very brief review of the subject.

This is not a theoretical treatise. Each section of the Code has been drafted by a person or persons who have practical experience of the system and particular conditions described. The names and addresses of contributors are listed in Appendix 2. The entire text has been revised at several meetings of groups of experts, and by the Editors. No section should be attributed to any one author.

III. Contents and limitations

The contents of this Code have been selected by examination of existing national and institutional documents, combined with special topics suggested by experienced scientific divers, plus consideration of the unique problems which arise from designing a text to be used internationally.

Wherever possible the views expressed in this Code are designed to be compatible with the treatment of the same topic in existing documents. In no sense is this Code intended to replace or supersede the more detailed treatments given in technical manuals. National legislation in any country takes precedence over recommendations and advice in this Code.

This Code does not apply to diving operations performed solely for sport or recreation.

This Code does not apply to commercial or industrial diving operations conducted in connection with construction, offshore petroleum, engineering, harvesting, cultivation or any other forms of commercial underwater work and employment.

This Code does not contain information on scientific methods or techniques which can be used in the application to specific scientific problems underwater.

The first-aid procedures discussed in this Code are not exhaustive and are not intended to replace first-aid manuals.

IV. Liability for use

The information in this Code is given in good faith and is based on the best experience available at this time. No liability can be accepted by the Confédération Mondiale des Activités Subaquatiques, its component bodies, officers or agents, or the contributors, or by Unesco for any loss, damage or injury suffered directly or consequently as a result of any diving activity or any related activity during which this Code was being used. Notwithstanding the professional and accurate information provided in this Code, many sections describe techniques that should not be attempted without consultation with the references cited. It is advisable to contact scientists who have already used these techniques in their research. The information contained in this Code consists of summary guidelines and a reference to sources. It should not be treated as sufficient on its own as a manual to conduct diving operations.

In publishing the information set forth in this Code, the co-publishers assume no liability not otherwise imposed by law. Each diver is assumed in the context of this Code to be voluntarily performing activities for which he/she assumes all risks, consequences and potential liability, unless otherwise agreed on by contract with the employer of the diver.

V. Notes on terminology

Whatever the circumstances, the basic principle adopted in this Code is that existing practices and codes should be adhered to wherever possible. The recommendations of this Code are largely supplementary to other documents so as to provide safe regulations in all circumstances.

In the drafting of each section of this Code it is assumed that all other relevant sections are also being complied with; that is, that divers have been trained to the required level on the equipment to be used, and that where two or more special conditions apply, e.g. under ice and in a remote area, the recommendations of both sections will be followed.

The terminology in the Code has not been standardized rigidly, since agreed definitions of many terms do not exist; it would be arbitrary and cumbersome to attempt this task. However, various phrases are used where instructions or recommendations are given and should be interpreted as follows:

MUST - There are no circumstances under which this recommendation may be ignored, e.g. Section 7.6: "Oxygen diving must only be carried out after personnel have received a full course of instruction from a Navy establishment or other establishment experienced with this mainly military equipment."

WILL/SHALL - Other than in exceptional circumstances this recommendation should always be followed, e.g. Section 6.1.2: 'All diving equipment shall be inspected by the diver for proper functioning at the beginning and end of each diving day."

SHOULD - Normal diving practice requires that this recommendation be obeyed but there may be circumstances in which it is appropriate to relax it, e.g. Section 6.3.4.3: 'The fullest possible report should be compiled by the Dive Marshal/Dive Supervisor/Person-in-charge and submitted to the Diving Officer."

CAN/MAY - Scientific diving may well benefit from employing this technique, e.g. Section 8.2.19: "Additional scuba systems may be carried and used to extend cave penetration distances or times."

SHOULD CONSIDER - A helpful hint that may indicate only a personal preference.

Technical terms, abbreviations and acronyms used in this text are defined in Appendix 14.

All measurements, especially depth, are referred to in meters, and other SI units where appropriate. Measurements in feet, used for instance with reference to the US Navy air decompression tables, are also referred to in the metric system where appropriate.

At several points in this Code there are references to equipment, boats, proprietary drugs and other items described by proprietary or brand names. This has been done only in order to give specific examples, or to make the discussion clear.

Such references do not imply any approval, endorsement, recommendation or condemnation of any product or material. Numbers in brackets, e.g. (8.3.28) in the text are cross-references to other sections in this Code.

SECTION 1. INTERNATIONAL LAW OF THE SEA

1.1. United Nations Convention, limits of jurisdiction & Council of Europe
In 1982 The Law of the Sea, United Nations Convention on Law of the Sea (UNCLOS) (Official Text 1983, published by Croom Helm, and St. Martin's Press, for the United Nations) was signed in Jamaica. The Convention document must be ratified by national legislatures before it becomes international law, but in the meantime it may be regarded as a norm to which many countries adhere in principle, in whole or in part.

There are no specific references to diving at sea in UNCLOS but there are many references to the conduct of marine scientific research. When scientists from one country conduct research on a ship which enters into the Exclusive Economic Zone (EEZ) or the territorial sea of another country, there are many obligations concerning notice of intent to conduct research, offer to accept observers and sharing the data which result. Much diving research is conducted from the shore, and when diving is conducted in foreign countries, scientists often work in collaboration with colleagues from the laboratories of that country. When direct collaboration is not involved, there may still be a requirement to obtain permits to dive from the civilian or military authorities.

The key point to note is that the UNCLOS requires that, even if you do not land or enter territorial waters, you should obtain permission to conduct diving research if you are within an EEZ, which commonly has a width of at least 200 miles.

Outside the EEZ the waters are international high seas, and the obligations of scientific divers are the normal ones of prudence and safety. The legal regime will be determined by the flag of registration of the vessel.

There are sections of UNCLOS relating to marine archaeology (Articles 149, 303). Article 149 describes artifacts found in the International Areas of the seabed. Article 303 encourages states to enforce national legislation on the protection of submarine cultural artifacts out to a distance of 24 miles from their coasts.

Council of Europe: The Council of Europe has drafted a Treaty on the Protection of the Underwater Cultural Heritage. The membership of the Council of Europe extends from Sweden and Norway to Spain and Turkey, including all the coasts of Europe with the exception of Albania. The Treaty requires the strict reporting of any archaeologic finds, and very strict control of site disturbance, which must be supervised by officially appointed or approved archaeologists. If in doubt, documents can be obtained from the Council of Europe, Strasbourg, France.

1.2. International recognition of diving training certificates
Several national organizations produce diving training qualification records (2.7) or identity cards which are recognized beyond their national boundaries. The American "C" card, which is issued by several certifying agencies, is widely recognized as a sports diving qualification. Some large scientific laboratories and university marine science departments, especially in the United States, run their own scientific diving programmes, and issue recognized qualification documents. Specialized groups, such as cave diving groups, provide qualification records that

are specialized and restricted only to the relevant kind of diving or environment. At a truly international level CMAS produces certificates which are linked to national standards by a procedure of equivalence. This is restricted primarily to sports diving training using scuba equipment (Appendix 13), although the 3-Star standard is accepted as suitable for scientific diving in almost all countries.

Since the conditions of work, insurance (2.5) and legal liability are different for an employed person, as opposed to a sports diver on vacation, CMAS introduced in 1980 a certificate for Scientific Divers (4.12; Appendix 10). This certifies internationally that the holder is authorized to work as an employed scientific diver in a place of research in their country of origin. The Scientific Diver Brevet is only issued to a diver who already holds the CMAS 3-Star Diver qualification. Countries which have a very strict regime of legal and insurance requirements for scientific diving may not regard the CMAS Scientific Diver card as sufficient proof of status. However, the card is an international guarantee of one simple fact: the holder is authorized to dive at work as a scientist in the country of origin. That guarantees a certain minimum status, after which further enquiries may clarify special details. Application forms for the Scientific Diver Brevet can be obtained from: CMAS, 47 Rue du Commerce, Paris 75015, France.

1.3. Cooperative projects

Some of the most effective diving research programmes have been multinational. In the planning of such a project it is vital to ensure that such aspects as legal responsibilities and liabilities are fully understood, and that all parties know what legal regime applies in the area of work. Insurance standards should be clearly stated, both personal accident and third party liability.

In the planning of multi-national projects, due regard must be paid to the probability that divers will be used to different types of equipment and methods of use. Time should be allowed for familiarization. It is essential that the Dive Supervisor in charge of on-site diving and the Diving Officer of the host establishment make clear to all divers what rules and code of practice(s) are to be used. This is especially important when divers from several institutions or countries join to work on a research ship. There must be formal briefings to establish the rules to be used and, if necessary, practice dives together, no matter how experienced the individual divers. The hallmark of a good scientific diver is an ability to support the diving team and improve its productivity by increased teamwork and efficiency, not to promote small, procedural points of particular diving practice.

SECTION 2. NATIONAL LEGAL ASPECTS AND ADMINISTRATION

2.1. Introduction

The purpose of this section is to describe and compare briefly the legislative regimes in a few countries. The subjects raised, and documents referred to, cannot be exhaustive, but they illustrate the topics which are the subject of legislation in many countries. In countries where no legislation at present controls the standards of either working diving or sports diving, the documents referred to here may serve as guidance as to what standards are desirable, and what would be excessive. A fuller review of these topics is given by Flemming (1985).

Regulations concerning diving safety and training are designed to apply to nationals in each country. Regulations do not usually contain any specific reference to the qualifications required of visiting divers from other countries. It is reasonable to assume that host institutes will check that visitors' standards are comparable with their own, and in many institutes there are established procedures and forms for making these checks. Foreign diving teams working without a host organization will probably dive according to their own regulations. In these circumstances they should still check to make sure that their practices will be compatible with those of the host country.

Traditionally most countries have only had diving laws which protected antiquities, or installations of a military nature, banned spearfishing or controlled access to marine parks. In the last ten years, statutory regulations have been introduced in many technically advanced countries, controlling the standards of diving training and safety. This is particularly true of France, the United Kingdom, Scandinavia, South Africa, Australia, the Federal Republic of Germany and the United States. The legislation has often been introduced rather hurriedly, and then modified. Since legislation designed to control commercial diving in offshore oil fields concerns quite different techniques and equipment from those used by scientists, such legislation is usually inappropriate when applied to scuba diving for research purposes. In several countries, scientific representatives have succeeded in obtaining complete exemption from commercial diving legislation, or at least partial exemption.

The legal situation tends to be complex in the technically developed countries, and changes from year to year. Scientists working outside their own country should enquire as to whether there are any statutory regulations about training levels, conduct of dives, medical standards, equipment, and insurance, etc. Scientific divers from many countries have been in contact with CMAS, and there is a general awareness of the problems caused by inappropriate legislation.

2.2. Examples of national legislation

National laws applicable to diving are usually subsections of wider legislation. Thus, diving regulations may be enforced as part of the regulation of offshore oil production, as part of the construction industry, as part of general safety regulations of factories or as part of universal safety regulations. It follows that the population to whom the regulations apply will differ from case to case. In one country diving in inland waters and coastal waters may be controlled, but not outside territorial limits. In another country, diving will be controlled if one is working with the oil industry, but not otherwise. Yet again, diving may be controlled if one is working for a salary, but not if one is an amateur or unpaid volunteer.

Most regulations specify standards of training and experience, but not a necessary route for obtaining the standard. Only the United Kingdom, the Federal Republic of Germany and South Africa at the date of writing this Code actually require that working scientific divers attend training schools which are approved by a government agency, and every training certificate is checked by a government agency. The United Kingdom has now successfully exempted this requirement for scientists and has reinstated sports diving standards as the recognized diving qualifications. In most countries sports diving training is accepted as sufficient for scientific diving using scuba, provided that employing institutions have an adequate supervisory program.

The following examples of legal documents applying to diving are given in alphabetical order by country. The comments are illustrative only, and should not be taken as an interpretation of the law. The original documents must be referred to.

Australia: To date there are no legislative requirements aimed specifically at scientific divers.Australia is a federation of six states and two territories, all of which have constitutional authority to legislate on matters affecting conditions of employment, fisheries, coastal navigation and maritime matters, historic shipwrecks, parks and inland waters. Additionally, the Federal Government has responsibilities for navigation, declared historic shipwrecks, national parks, resources and fisheries.

Legislation exists in some states as to the qualifications and registration of 'working divers', which could include divers employed on scientific work. It is necessary under the various employment awards for minimum wages and conditions to apply to some categories of employed divers. This includes workers compensation cover.

Some equipment, including cylinders and valves must meet the standards of the Standards Association of Australia, Australian Standard Rules for Underwater Breathing Operations, 1976 and State Legislation.

Most universities and research organizations using divers have some form of code of practice; possibly the best known is the Code of the Great Barrier Reef Marine Park Authority. It would be difficult for a diver in Australia to hire equipment or have cylinders filled if a recognized diving qualification could not be produced. A CMAS 2-Star brevet or higher would normally be recognized but a check-out dive may be requested.

There is currently a code for basic diver qualifications, with a follow-on unit for scientific diving being drawn up by the Sub-Aqua Association of Australia (SAA). Within two years this code could be expected to be enforced by State Legislation.

Austria: There are no special laws and restrictions for scientific diving in Austria. Regulations are the same as for sports divers. A scientific diver must be CMAS 2-Star or higher.

Diving is forbidden at some local archaeological sites and in private lakes. Every diver must obtain permission from the local residents or the 'Bundesdenkmalamt' for archaeological sites.

Canada: Canadian Standards Association, CSA Standard 2275.2 'Occupational Safety Code for Diving Operations'.

Note: These standards are being gradually adopted province by province. The Canadian Association for Underwater Science is pursuing the same policy as the American Academy of Underwater Sciences and is seeking complete exclusion for scientific diving, on the grounds that the standards are only appropriate to commercial and industrial types of diving.

Chile: Diario Official de la República de Chile, May 1984, no. 31.876, Titulo IV et. seq. 'Del Deporte Submarino'.

'Reglamento de Buceo para Buzos Profesionales', Reglamento 7-54/4, Armada de Chile, Direcciión General del Territorio Maritimo y de Marina Mercante, 1982.

Note: The regulations recommend the use of the US Navy decompression tables and include depth limits on different types of equipment, medical standards, etc. Frequent reference is made to the need to consult or refer to the Maritime Authorities.

The Federal Republic of Germany: Richtlinien für den Einsatz von Forschungstauchen, Hauptverband der gewerblichen Berufsgenossenschaften, 53 Bonn 1, Langwartweg, 103 (ZH 1/540). This document describes regulations for scientific diving and lists the following official documents: Working diving operations, VBG 39; Light diving apparatus, ZH 1/237; Construction of buoyancy equipment for divers, ZH 1/541; and Saturation diving from underwater habitats, ZH 1/516. Also listed are accident prevention regulations: Compressors, VBG 4; Pressure vessels, VBG 17; Floating apparatus, VBG 40a; Gases, VBG 61; and Oxygen, VBG 62.

Note: The Federal Republic of Germany diving regulations are very strict, with a strong requirement for on-site recompression facilities, government approved training qualifications, etc. There is a strong requirement for surface tended life-lines. There is strict segregation between amateur and working diving groups. There have been several research habitats developed in the Federal Republic of Germany using government research funds, and a great deal of experience has been obtained in the operation of these systems. There are three separate sets of laws applying to sports diving, professional industrial diving and scientific diving.

France: Ministère du Travail, Mesures particulières de protection applicables aux scaphandriers, 1977.

Centre Nationale de la Recherche Scientifique, Inspection Générale de l'Hygiène et de la Securité: Instruction Technique sur la Securité lors des Plongées Subaquatiques, 1978.

Note: French legislation applies to employed divers. Regulations apply to three classes of divers: qualified to dive to 30 m, 50 m and greater than 50 m. Maximum permitted depth on compressed air is 60 m. The regulations specify a detailed set of decompression tables based on repeat dives and a range of surface intervals. French marine research stations have individual codes of practice and regulations to control the standards of diving within the general standards laid down by law, and by the CNRS. There is a strong move (1985) to increase cooperation and communalize standards between laboratories.

Ireland: Irish Diving at Work Act, 1984 which refers to the Irish Factories Act, revised 1982. This regulates diving on a factory site which for the purposes of industrial diving is all-inclusive. Scientific diving is specifically excluded by the Irish Department of Labour from these regulations.

Note: Health and safety legislation which may bring scientific diving under government regulation in much the same way as in the UK is currently being written but will probably be indefinitely postponed because of the cost to industry of implementation of health and safety legislation which will, by its nature, be more all-encompassing.

Amateur and professional scientific divers commonly work together; joint projects involving sports divers in scientific projects controlled by full-time diving scientists have been organized.

both by individual universities and the Science Officer of the Irish Underwater Council. Local government funds have been used to partially defray costs of at least one major scientific project studying pollution in Dublin Bay (Clarke et al., 1986). The Irish Underwater Council considers that selected divers having suitable sports diver qualifications are covered under the general insurance policy carried for club divers while involved in organized and approved scientific diving projects.

The Shellfish Act prohibits divers taking shellfish for any purpose including scientific without a special licence from the Department of Fisheries.

Italy: No laws at present restrict the practice of scuba diving. However, insurance is a serious problem for people working while diving, and cover can be provided through the Centro Italiano di Ricerche e Scienze Subacquee. New legislation is under discussion. Amateur and professional co-operation is encouraged.

The Netherlands: The Netherlands does not yet have generally applicable laws or regulations on diving activities of scientific and sports divers.

General: Legal provisions covering professional diving activities have, however, been in preparation for a considerable time. These provisions will supplement the general laws on working conditions, which inter alia contains rules on safety and health. The first draft for legislation on diving also takes into account the European Economic Community (EEC) guidelines in this field (Mines Safety and Health Commission). It may be assumed (late-1986) that it will be some considerable time yet before this legislation on diving will come into force. Information on this (future) legislation may be obtained from: Directoraat Generaal van de Arbeid, Postbus 69, 2270 MA Voorburg, The Netherlands (Tel. 070 694001).

Zeeland regulations: In 1980 the Province of Zeeland drew up regulations prohibiting diving as a sport in Zeeland waters without a permit issued by the provincial authorities. Persons who can prove that they dive in Zeeland for scientific or other professional purposes do not need this permit. Information on the Zeeland diving regulations can be obtained from: Provinciale Griffie Zeeland, Postbus 42, 4330 LA Middelburg, The Netherlands (Tel. 01180 31011).

Finding objects under water that have an archaeological value: In principle, the Dutch Monuments Act also applies to the territory underwater. This act provides that finds with a scientific or historical value have to be reported to the competent authorities (usually the local mayor or the town office). Further, the act prohibits digging for objects with a scientific or historical value without a permit. Information on searching for, or finding, historical or archaeological objects underwater can be obtained from: (1) Rijkscommissie Oudheidkundig Bodemonderzoek, Kleine Haag 2, 3811 CD Amersfoort, The Netherlands (Tel. 033 12648); (2) Drs Thijs Maarleveld, Ministerie van W.V.C., Postbus 5406, 2280 HK Rijswijk, The Netherlands (Tel. 070 949393).

Voluntary Code of Practice: The Nederlandse Onderwatersport Bond (N.O.B., Dutch Underwater Sport Association), a member of CMAS, has drawn up safety regulations that are binding on its members. The N.O.B. has addresses of members who can give information on archaeological, biological and other scientific aspects of diving in the Netherlands. The address of the office of the N.O.B. is: Nassaustraat 12, 3583 XG Utrecht, The Netherlands (Tel. 030 517014).

New Zealand: Department of Labour, Safety in Construction, No. 15, Code of Practice for Underwater Diving. This is a guidance document, not a regulation. Shown here rather than in

(2.4) because it is promulgated by a government agency. Actual legislation and regulations concerning diving are scattered through the Construction Act; Construction Regulations; Fisheries Regulations; Merchant Shipping Act, wreck and salvage of ships and aircraft; Mining Act; Petroleum Act; Antiquities and Historic Places Acts. The Underwater Association Code of Practice for Scientific Diving, 2nd edition, (Flemming; Miles, 1979) has been widely used in New Zealand.

Norway: A draft on revised regulations on inshore commercial diving was circulated in Norway (1987). In their present form the regulations require underwater communications for all commercial diving and a chamber on location whenever dives are conducted to a depth below 24 m. As a reason for the new regulations, the national labor commission lists safety as well as ensuring that commercial divers as a trade group will not be deprived of jobs as a result of sports divers accepting assignments for lower fees than their professional counterparts.

The authorities will legalize sports divers on commercial assignments by requiring that the divers hold a 'class 1' commercial diver's licence issued by the Norwegian State's school of commercial diving to perform as commercial divers.

It is still not clear whether diving instructors and scientific divers may be exempted from the new regulations. Scientific divers are, of course, no threat to the commercial labour force, but Norwegian authorities are reluctant to grant any exemptions at all. Commercial divers have stated that if they have to comply with strict regulations they will not see any other group getting preferential treatment. It is evident that this attitude is motivated primarily by the desire to form and perpetuate a monopoly. There seems to be little public interest in the scientific divers' situation. The Norwegian Sports Diving Association (Norges Dykkeforbund) is trying to protect the rights and interests of scientific divers and sports diving instructors. Semi-professionals may not be strongly affected since the regulations will be hard to enforce on the extremely long and remote Norwegian coastline.

Sweden: To date there are no legislative requirements aimed specifically at scientific divers. There are different local safety codes being used throughout the country but they vary in important respects. This has created insurance problems for institutions.

There is an authority appointed by the government for legislation of diving certification. The authority is organized within the Swedish Navy and shall, on request, certify divers who meet the demands of identified levels of diving education in Sweden. The three levels are related to:

(1) The Contracting industry, (2) The Salvage industry, and (3) Scientific diving.

Scientific diving training did not start until 1986. The training course is six weeks long. Certification of scientists who are currently diving in the course of their work is part of an early transitional period in the training schedule. It is proposed that diving training will be adopted and incorporated into the Swedish universities' notes system.A national safety code for scientific diving is under revision and should be presented in its new form in 1989 or 1990. A preliminary code is available from the University of Gothenburg.

Presentation of diver certification from any national or international body, especially the CMAS Scientific Diver Brevet, should give a visiting diver access to scientific diving in Sweden.

South Africa: Department of Labour, Factories Machinery and Building Work Act, 1941, Diving Work: Diver-Scientists, Chapter VII of the Regulations, Code of Practice for Research Diving. South Africa Bureau of Standards.

Note: South African regulations were negotiated fully with the cooperation of the scientific diving community. The scientific divers are represented by Barologia, the Association of Diving Scientists. The regulations make it difficult for amateur and employed groups to work together in the same team, but two self-contained teams may co-operate.

The United Kingdom: The Merchant Shipping (Diving Operations) Regulations, 1975. S.I. No. 116 (applicable on British ships outside territorial waters and foreign ships within British waters).

Health and Safety at Work (Diving Operations) Regulations, 1981. S.I. 399 (applicable to all divers anywhere in inland waters or at sea, on oil rigs, etc. within territorial waters or on the UK continental shelf, provided that the divers are self-employed or working as paid employees. (Amateurs are excluded.)

The Merchant Shipping (Diving Operations) (Amendment) Regulations, 1976. S.I. 2062. (This excludes scientists and archaeologists from the Merchant Shipping (Diving Operations) Regulations, 1975.

Note: The Health and Safety Regulations are the most important, and these lay down standards of training, certification, the appointment of dive supervisors, medical standards and procedures for the conduct of dives. Only doctors approved by the Employment Medical Advisory Service are entitled to give medical certificates to working divers. Exemptions are in force to permit groups of divers to be made up of both employed and amateur divers conducting scientific research, and an amateur diver of suitable experience is permitted to supervise a dive conducted by an employed diver. The minimum training standard for a working scientific diver is BSAC Advanced Diver or CMAS 3-Star. That is to say, sports diving standards are accepted and recognized as sufficient for a working scientific diver using scuba.

The United States of America: Occupational Safety and Health Administration (OSHA), Department of Labor, Part 1910 of 29 CFR, Subpart T, Commercial Diving Operations. (See Federal Register, July 1977, Vol. 42, No. 141, pp. 37650-37676, Final Standard.) The text of exemption covering scientific diving is contained in the Federal Register Vol. 47, No. 228, Friday, November 26, 1982, Rules and Regulations, pp. 53357-53365. There is a later amendment of January, 1983. Those requiring more information should contact the Secretary of the AAUS, 947 Newhall Street, Costa Mesa, California 92627, USA.

Note: The American Academy of Underwater Sciences has obtained exclusion for scientific divers from the OSHA Regulations. Most major universities and marine institutes have very thorough and practical codes of diving training operated at the institutional level. Divers visiting American institutes from abroad will usually have to satisfy training, legal and medical standards, established by the institution where they are going to work. To operate under the exemption, OSHA requires that 'Scientific diving be under the direction and control of a Diving Program utilizing a Diving Safety Manual and a Diving Control Board meeting certain specified criteria'.

2.3. Discussion

Scientific diving has an extremely good safety record, and there is no evidence that accidents or fatalities were frequent before legislation was introduced in any country or that accidents have increased or decreased after legislation was introduced. (See Flemming [1981] for analysis of diving accidents in Europe, and Schenk and McAniff [1975] and Sharkey and McAniff [1982] for accidents in the USA). It follows that legislation should serve the purpose of guaranteeing the status quo, rather than effecting major changes in practice. Where legislation exceeds this level of restriction, the monetary cost of scientific diving increases, work is delayed and safety may even decrease as divers perceive that the regulations are generally irrelevant and unenforceable. For a comparative discussion of national legislation see Flemming (1985).

2.4. Examples of codes of practice

In several countries there are important documents providing guidance on diving practice at a level of recommendation, rather then mandatory legislation. These documents are usually designed in a very positive way, providing interpretation of legal matters and advice on diving in sea and freshwater conditions found in that country.

The United Kingdom: Underwater Association for Scientific Research (ed.) The Code of Practice for Scientific Diving. Natural Environment Research Council, publisher. 3rd ed., 1979 (Fourth edition in preparation).

Canada: Canadian Association for Underwater Science, Standard of Practice for Scientific Diving. Draft, February 1984.

Italy: CNR (1980) Normative di Sicurezza per l'Immersione Scientifica. (DeStrobel and Colantoni). SACLANTCEN Code of Practice for Scientific Diving. 1984.

South Africa: South African Code of Practice for Scientific Diving, published by Barologia, Department of Oceanography, University of Cape Town, Rondebosch 7700 (adapted from 2nd ed. of the Underwater Association Code of Practice, by permission).

The United States of America: American Academy of Underwater Sciences (AAUS). Standards for Scientific Diving Certification and Operation of Scientific Diving programs 1984.

Woods Hole Oceanographic Institution. Diving Safety Manual. 1983.

Miller, J.W. (ed.). NOAA Diving Manual. US Government Printing Office. 1979.

California State Universities and Colleges. Minimal Standards for Scuba Diving Certification and Operation of Scuba Diving Programs. 1981.

University of Rhode Island. Narragansett Bay Campus Research Diver's Manual. 1985.

Note: These documents are just a few of those prepared by major universities and research institutes. Many sections of these institutional documents are deliberately phrased to be as similar as possible, and to comply with the minimum standards of practice for scientific diving as set out by the AAUS.

2.5.Insurance

Divers carrying out scientific work underwater should be insured.

2.5.1. Introduction

Insurance legislation differs widely from country to country, and between government organizations and private organizations. In some cases employed divers may be covered automatically by virtue of their employment.

Institutes, university departments or groups of divers who are, or wish to be insured commercially, should arrange consultations between their insurers, the administrators and the scientists responsible for diving activities to ensure that adequate insurance cover is provided.

The following points are relevant to such consultations:

1. Size and training standard of the diving team.
2. Medical examination standard.
3. Code of practice or regulations followed.
4. Operating areas and depths.
5. Apparatus and techniques involved.
6. Equipment maintenance standards.
7. Liaison with marine insurers if research vessels are involved.
8. Compliance with statutory regulations where necessary.

It is the institute's responsibility to take all reasonable precautions against accidents during diving activities. This demands standards of medical fitness and training, adherence to an approved code of practice and the provision and maintenance of suitable equipment.

In all institutes diving is a voluntary activity and in some institutes divers are required to sign a disclaimer to that effect. This serves first to draw the individual's attention to the demanding nature of the duty undertaken and second to indicate that the diver knowingly waives some rights. The individual can only press a claim against the institute by proving negligence on its part. The diver is entitled to refuse to dive under any circumstances in which there is reason to believe that there is evidence of negligence, for example the provision of defective equipment.

Since the individual has little chance of a successful claim against the institute in the event of an accident occurring if all reasonable precautions have been taken, the diver is strongly advised to take out personal accident insurance. This and all other policies such as life insurance and mortgage protection policies should have specific endorsements for diving risks in connection with employment, whether paid or unpaid, added to the policy document. Under certain circumstances it may be possible for the employing institution to reimburse divers for the excess premium required to obtain or maintain the usual life insurance policies on a personal basis.

Scientific diving associations such as AAUS, CAUS, UASR, CIRSS, etc. provide advice on insurance for divers.

2.5.2. Classes of risk

Several different classes of risk and liability should be considered, not necessarily in order of importance:

1. Liability of the employer for claims against the employer by an injured diver or his/her dependent(s).
2. The liability of the employer for claims against the diver by employees or the general public arising from diving accidents.
3. The liability of any diver for claims against the diver by other divers or members of the public arising from diving accidents.
4. Personal accident insurance for individual divers compensating them or their dependents for accident or loss of life caused by diving while employed.
5. Personal accident and third party liabilities arising from boat-handling, which is not usually included in a diving insurance arrangement.

2.5.3. Standard group insurance policies

Sports diving organizations and national diving federations often provide third party public liability insurance for their members as part of the membership rights, the cost being part of the subscription fee. Personal accident insurance can usually be obtained through agents who are familiar with diving risks. In both cases, these policies become invalid if the diver undertakes paid or professional work for profit.

For this reason, some scientific diving associations have negotiated group insurance to cover scientific work only. Examples are the CIRSS in Italy and the UASR in the UK. In both cases, a member of the association receives insurance cover while employed in scientific diving activities. For addresses of scientific diving associations, see Appendix 8.

2.6. Equivalent job titles

Detailed descriptions of responsibilities or personnel will be given in Section 3, but a broad equivalence of titles is important for legal purposes and insurance evaluation and is thus relevant here. The titles of people responsible at different levels vary from country to country but the overall structure is consistent. The titles and structure listed below will only apply in larger institutes or departments; in smaller establishments some of the roles can be combined. The job titles illustrated below have been chosen from the line-management structures in several countries and are shown as examples (Table 2.1).

In general terms Level 1 is the ultimate legal and employing authority in the organization. Level 2 is the senior individual, individuals, or committee responsible for overseeing diving training and safety. Level 3 is the responsible administrative officer charged with carrying out the policies and directives of the Diving Control Board. Level 4 is the professional technical expert responsible for all technical, administrative and personnel aspects of diving training and safety. Level 5 is the person responsible for diving safety and conduct at any particular dive site. Level 6 describes the diver who is in charge underwater when a buddy pair dive together. Level 7 describes the diver at work. Level 8 is a diver whose training has been approved, but is not yet complete.

2.7. Qualification records and authorization to dive

Certification of the diver's training courses, medical examinations and diving records should be in an officially recognized diver's record card or logbook. In a few countries these logbooks must contain records of every dive with specified details required by law. In most countries, a sports diver style of logbook is sufficient.

With regard to training records the following items should be recorded and signed or approved with the appropriate stamps and dates:

1. Senior officer's approval to undertake diving course.
2. Signature on a voluntary declaration form.
3. Medical examination and X-rays passed prior to first dive.
4. Theoretical written examination passed.
5. Pool examination passed, or shallow water tests.
6. Open-water basic training with scuba completed.
7. Open-water practice period as a Trainee diver completed.
8. Authorization to dive.

Table 2-1. Examples of equivalent job titles

Level	UK	USA	CANADA	NORWAY
1.	Director of Institute, or Chancellor of University	President of the University	Chief Executive	Governing Board, or Rector of the University
2.	Diving Officer	Diving Board of Control	Diving Control Board	Diving Control Board
3.	-------------	Diving Officer	Diving Officer	Departmental Diving Officer
4.	Chief Diver	----------	---------	Diving Officer's Appointee
5.	Dive Marshal/ Dive Supervisor	Lead Diver/ Dive Master/ Supervisor	Person in Charge	Lead Diver
6.	Dive Leader	Dive Leader	Dive Leader	Dive Leader
7.	Diver	Diver	Diver	Diver
8.	Trainee	Diver-in-training	Diver-in-training	Trainee

In some countries or institutions diving authorizations are depth limited at intervals and may expire if dives are not completed by regular dates. These systems are effective where it is a simple matter for divers to obtain dives in deep water in order to keep in date, but may result in unnecessary journeys and expense when an institute is located far from deep water. In the latter case a work-up dive schedule is preferable before each major diving project (4.9.1; 4.9.2; Table 4-1).

2.8. Pay

Some institutions or organizations provide a pay bonus or supplement for scientists who dive in the course of their work. This practice does not compromise the general principle that scientific divers are employed primarily as scientists, and that diving is only a voluntary element intheir research programmes. In some countries the acceptance of diving pay may change the legal status of the diver.

Supplementary pay schemes are usually based on either:

1. A proportion of the scientist's daily pay added to each day on which diving takes place.
2. A sum proportional to the number of atmospheres x minutes for which the diver is either actually underwater or fully kitted up on the surface before and after a dive.
3. A fixed sum which is intended to compensate the diver for discomfort or outdoor time or

additional personal costs incurred.

2.9. Volunteers

Employed/working scientific divers may frequently dive in company with volunteer assistants or teams in the following circumstances:

1. Where an employed teacher or supervisor dives with students in the course of scientific instruction or research.
2. Where students or amateurs volunteer to join a selected team to conduct research and assist a professional research worker.

In these cases the amateurs/volunteers should be regarded as if they were temporary employees, and their diving should be conducted according to the same code of practice and laws as those applying to the institute/ university/employer. The only exception may be the legal requirement to have attended specific courses of training relevant only to employed divers. This protects the institution from the allegation that it is allowing amateurs to dive in an unsafe manner while using their labour and goodwill.

3. Where a professional researcher or scientist supervises members of a club or voluntary group who have offered to do environmental studies in the region where they normally dive and ask for scientific advice.
4. Where amateur divers discover an archaeological site and are supervised by a visiting professional.

In these cases diving will almost certainly be conducted to the normal standards of sports diving and be covered by sports diving insurance. Neither the visiting professional, nor their employing institution takes responsibility for the diving training standards, conduct of dives, choice of dive-sites or times of dives. The visiting professional scientist should make sure that their own diving practices are compatible with those of the amateurs, and that their insurance is not invalidated by diving without professional companions.

It cannot be stressed too strongly that the above examples are only examples from a range of possibilities, and that the law has never been tested in this area. Co-operation between amateur and professional scientific divers has proved beneficial to aquatic science over the last two decades and is very widely practised. It is hoped that this co-operation will continue.Volunteer amateur divers working for an institution, whether paid or not, should sign a declaration form outlining the terms agreed on, and making it clear what standard of diving and code of practice is being applied.

Diving conducted in the mode of paragraphs (3) and (4) above should not be regarded formally as scientific dives, or logged as scientific dives, except for the professional scientists involved. This helps to preserve the statistical records of scientific diving, to avoid over-counting the numbers of supposed scientific dives and to identify the true categorization of any accidents or incidents that may occur.

SECTION 3. ORGANIZATION

3.1. Chain of command and responsibilities

The chain of command suggested here is appropriate to fairly large organizations. In the case of small groups many of the responsibilities will be combined in one person, or, in the absence of superior authority, assumed communally by the members of the group. Even where no long chain of command exists, divers still must have clear-cut responsibilities for their own and each other's safety. The outlined chain of command elaborated on here demonstrates the nature of the level of responsibility in the chain of command and is not intended to be a formal system, with every post filled by a different person, except in the larger institutes (See Table 2.1).

3.1.1. Corporate responsibility [Level 1]

Diving groups are operated by authority of the President, Director or Head of Department of a research establishment, university or polytechnic.

The President, Director or Head of Department is responsible for appointing in writing a suitable Diving Control Board or an Institute Diving Officer and for ensuring that adequate finance and material support is made available to train and operate the diving group safely. If diving legislation of a health and safety nature is enacted by a government to regulate diving at work, the President, Director or Head of Department is responsible for ensuring that the provisions of the acts are adhered to. In small groups, one person should take responsibility for ensuring that regulations are known and complied with.

3.1.2. Diving Control Board [Level 2]

An institute or university, or other corporate body may or may not have a Diving Control Board to set standards and work practices for the particular nature of the work and the local diving conditions. A Diving Control Board is most relevant in the case of a university or large institute where numerous component faculties or departments have differing interests and need to be represented. This group sits to formulate procedures and considers the best way to get the work done taking into account safety and operational conditions. This system of management is most commonly used in the USA and Canada.

In a university or institute where a great deal of diving is going on, the Diving Control Board should be as broadly based as possible so that the needs of all research diving groups are taken into consideration. The organization of the Diving Control Board can take whatever form best suits the size and experience of the research groups. In the case of an institute which is beginning diving operations, or for some other reason has little or no in-house expertise in scientific diving, the President, Director or Head of Department can appoint an external member of this Board, which can consist of the external member alone.

3.1.3. (a) Diving Officer [Level 2]

Where an institute or university does not appoint a Diving Control Board, the Director or representative of the corporate administration shall appoint a senior scientist as Institute/University Diving Officer. This person shall be the corporate officer responsible for the organization and policies of the diving programme.

This officer should co-ordinate the scientific programme of the group and ensure that the divers are properly trained, equipped and led, and that the necessary administration is dealt with.

This officer should have a good working knowledge of diving, but need not necessarily be in-date (4.9.1) with personal training.

This officer should appoint a Chief Diver and defer to the views of the latter on all matters concerning diving safety.

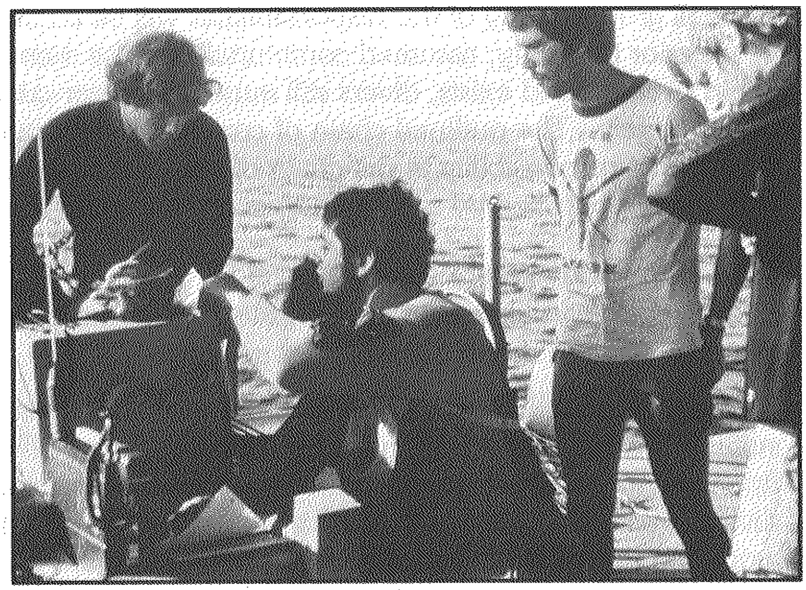


Photo 1: All members of the dive team should understand the chain of command and their individual responsibilities within it. *Photo: G. Stanton*

The Diving Officer may hold the post of Chief Diver, if he/she has the necessary qualifications and experience.

It is the responsibility of the Diving Officer to ensure that there is never any doubt about the chain of command.

It is the responsibility of the Diving Officer to take the initiative to produce, with the Chief Diver and the Scientific Project Leader, a joint operational instruction relating to each project. This will detail scientific objectives, operational procedures and safety precautions.

The post of Institute Diving Officer is not identical with the post of Diving Supervisor who is often the specified person in charge of diving operations in some commercial diving regulations. In a research context the senior person responsible for overall conduct of diving operations should have a general knowledge of the scientific programmes and requirements and also have sufficient seniority to appoint and report upon personnel. The Chief Diver may have insufficient seniority from this point of view. The Institute Diving Officer, thus, has the responsibility to comply with relevant government diving regulations in organizing diving operations, and the President, Head of Department or Director is responsible for the institute or university to ensure that this happens.

3.1.3. (b) Diving Officer [Level 3]

Where an institute or university has created a Diving Control Board, the Board shall advise the President, Director or Head of Department on the appointment of the Diving Officer. The Diving Officer has the responsibility to carry out the policies of the Diving Control Board and is a member of the Diving Control Board. The Diving Officer must have several years of research or scientific diving experience, and should be an in-date diver, with a thorough knowledge of diving theory, safety practices and operational procedures. This pattern of management is most common in the USA and Canada.

3.1.4. Chief Diver/Diving Officer's Appointee [Level 4]

Institutes or universities that do not appoint a Diving Control Board, and do appoint a Diving Officer with scientific seniority, should also appoint a Chief Diver. The Chief Diver should be appointed by, and report to, the Diving Officer. The Diving Officer is responsible for choosing for this post a diver who can be trusted to act as the nucleus for a safe diving team. This system of management is used in British and some European institutes. The responsibilities of the Chief Diver overlap considerably with those of the Diving Officer in establishments with a Diving Board of Control; in subsequent sections of this Code the term Diving Officer/Chief Diver will frequently be used to describe personnel with these responsibilities.

For this post, a minimum formal qualification should be at least at the level of CMAS 3-Star or NAUI Level IV (Advanced Diver), with a minimum of 50 scientific dives. In a large institute the Diving Officer should ensure that the diver appointed has in addition the personal qualities and experience normally appropriate to a CMAS 4-Star diver and a wide experience of working underwater.

The Chief Diver has full responsibility for all matters connected with diving safety, including training and equipment. It is ultimately at the discretion of the Chief Diver that an individual engages in diving for an institute. The Chief Diver is broadly equivalent to the Diving Supervisor positions referred to in some commercial diving legislation. In a large institution several teams of divers may be operating at different locations, and the Chief Diver will delegate responsibility for diving safety in each group to a designated individual.

All members of a research establishment including the Diving Officer are expected to defer to the views of the Chief Diver on safety provisions.

3.1.5. Chief Scientist/Project Leader/Principal Investigator

In all scientific diving there shall be a person responsible for the scientific objectives and line management aspects of the project. This person is usually known as the Chief Scientist, Project Leader or Principal Investigator. For projects requiring diving support the Chief Scientist is often not a diver and should consult the Diving Officer at the earliest possible stage in project planning.

The Chief Scientist will defer to the views of the Chief Diver, Dive Marshal or Dive Leader on matters connected with safety. This must be regarded as a condition for the undertaking of any diving project.

3.1.6. Dive Marshal/Dive Supervisor/Dive Master/Person in Charge [Level 5]

A Dive Marshal or Supervisor will be appointed from among the divers by the Chief Diver, if he/she does not himself undertake the duty.

During the preparation and carrying out of any particular diving project for which he has been appointed, the Dive Marshal has the responsibilities of the Diving Supervisor, as defined in some commercial diving regulations.

Minimum qualification is at the equivalent level of CMAS 3-Star (NAUI Level IV, Advanced Diver) with some scientific diving experience, but the Chief Diver must additionally be satisfied that the diver appointed understands the work task and can carry out the duties safely and efficiently.

The Dive Marshal has full operational responsibility for a diving expedition working under the scientific direction of the Chief Scientist. It shall be the responsibility of the Dive Marshal to ensure that the conditions and practices laid down by this Code are complied with on site.

It may happen that the Chief Scientist, if he/she has the appropriate diving experience, could be appointed as the Dive Marshal for a particular operation. However, in some establishments this is regarded in general as an undesirable practice, since it is considered that the Chief Scientist's understandable wish to finish a task may overrule better judgement on safety. It is therefore recommended that the Dive Marshal and Chief Scientist should usually not be the same person.

3.1.7. Dive Leader [Level 6]

A Dive Leader will be appointed from among the divers by the Dive Marshal. The Dive Marshal may undertake the task of Dive Leader.

The Dive Leader has operational responsibility for a dive, and works under the orders of the Dive Marshal/Supervisor and under the scientific direction of the Chief Scientist.

3.1.8. Diver [Level 7]

Divers are expected to work under the instructions of the Dive Leader, but if they are not satisfied with any aspect of the project they should not be ordered to continue. Every diver has the responsibility to ensure that all personal logbooks are kept up to date, and the terms of any regulations complied with.

Ultimate responsibility for safety rests with the individual scientific diver. It is the diver's responsibility and privilege to refuse to dive if, in his/her judgement, conditions are unfavorable or unsafe, or if he/she would violate the dictates of their training or the provisions of this Code. No scientific diver shall ever be coerced to dive or be penalized for not diving. It is the responsibility of the diver to terminate the dive, without fear of penalty, whenever he/she feels that it is unsafe or unwise to continue, unless it compromises the safety of another diver. No research dive-team member may be permitted to dive for the duration of any known condition that may be likely to adversely affect their own safety and health or that of any other team member. Each scientific diver shall conduct a functional check of their diving equipment in the presence of the diving buddy or tender.

3.1.9. Trainee/Diver-in-training [Level 8]

A scientific diver may be defined as a trainee, or have trainee status, in three different circumstances:

1. During initial instruction the diver does not yet have a sufficient number of dives and has not completed the necessary lectures, tests and examinations. This is a diver-in-training.
2. After completion of the required training course, a scientific diver may still need to obtain experience of scientific methods, experimental techniques or methodology by gaining working experience with a more qualified scientific diver.
3. When new experimental methods are to be used in extreme or unusual environmental conditions, a scientific diver may have to adopt trainee status in order to gain experience working alongside personnel who already have experience of the conditions.

3.1.10. Temporary Diver (See also 2.9)

A Temporary Diving Permit at an institution may be issued to a visiting diver from another institution, or from abroad, or to unpaid volunteers participating in diving for only a few days.

Temporary staff must have appropriate diving qualification, either of a sports, scientific or commercial nature. The Chief Diver/Diving Officer will generally require Temporary Divers to undergo one or more supervised familiarization dives. Portions of the institute diving requirements may be waived at the discretion of the Chief Diver/Diving Officer. Waiver and indemnity forms may be required (Appendix 9).

3.1.11. Ship's Master

The Master of a research or other vessel which is acting as a mother ship from which diving is taking place shall be consulted adequately in the planning stage of a dive. This is particularly important when divers from one country are diving on a vessel supplied by another country because of the difficulties of language and differences in practices.

The Master's word is final with regard to all actions on or near the vessel. This applies to launch and recovery of boats and whether diving can take place. In particular, the Master may consider that diving is not permitted if the requirement to stand by or to manoeuvre the vessel for rescue purposes would endanger the vessel itself.

The Master is responsible for displaying signals and lights from the vessel indicating that diving is taking place.

3.2. Delegation of duties

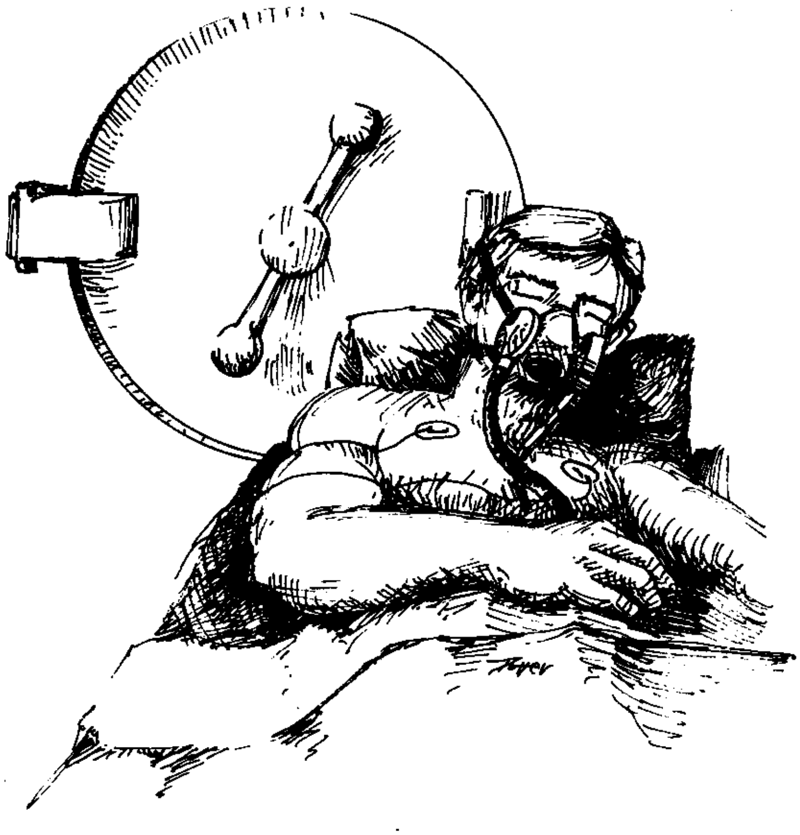
Duties that have been allocated to an individual may be delegated with specific authority to allow the delegate to carry out the task, but responsibility remains with the delegator. If the need to transfer responsibility does arise, for example when the Diving Officer or Chief Diver is on vacation or on sabbatical, the appointment of a replacement officer must be approved by the appropriate higher authority.

On the dive site, where the Person-in-Charge or Lead Diver wishes to dive, the duties for on-site supervision can be delegated to another individual with suitable qualifications by procedures that are standardized within the institution's diving programme.

3.3. Diving with other groups (see also 1.3)

Where divers from two or more institutions are planning to dive together in a joint project, it is usually best for the Diving Officers to agree on using one of the existing manuals or codes of practice, which shall apply to all the divers. This is the simplest procedure, provided that the methods of diving are reasonably similar, and the divers are given time to read the necessary documents and adapt to their requirements.

If it is not possible, or necessary, to agree on one of the existing safety manuals, the Diving Officers or Chief Divers should find out which of their procedures are the same, similar or in need of modification to allow the two (or more) diving groups to work together. A standard operating code for the conduct of the work must be agreed on and clearly communicated to all the divers and boat personnel involved. It may not be necessary for the personnel of the two groups to actually dive together as the work can go on in parallel or alternating dives; but it is important that each group knows the procedures of the other group, and that these procedures be brought to a common system, if possible, while the groups are in logistical or project contact. At the very least, divers from either group must be able to carry out emergency rescues on members of the other groups without incompatibility of equipment or technique.



SECTION 4. TRAINING AND MEDICAL EXAMINATIONS

4.1. Introduction

This section deals with the factors requiring attention in the preparation of personnel for diving. These include medical certification, personnel selection, fitness, gender factors, theoretical and practical training logbooks and qualification records. Training varies from country to country, and even though some of the recommendations here might exceed the present standards used locally, it is recommended that this section should be adopted as the minimum standard.

4.2. Medical certificates

In most countries, no statutory obligation is placed on establishments to require specific medical examinations for scientific divers. In some countries self-regulation based on the peer system obligates establishments to a common standard. In other countries legislation has been passed that sets the frequency and type of diving medicals, as well as the duration of validity of medical certificates. Generally, legislation has taken the form of commercial diving regulations, which are inappropriate for scientific diving.

There is a considerable range in working conditions and fitness requirements for scientific divers. For example, the medical standard required of a student collecting snails at 10 m is obviously not the same as that required for a researcher working at 200 m in saturation for 3 weeks. The vast majority of scientific dives are done to a depth of 20 m or less using scuba and entail light work such as collecting and sampling. Scientific diving activity is often seasonal and sporadic. There is no rationale for subjecting shallow-water divers to as rigorous a medical evaluation as deep water and extreme exposure divers. In response to these variables, two medical standards have been established in this Code allowing for different circumstances and frequency of diving. A number of authoritative medical check-sheets for scientific diving have already been produced which meet the guidelines for this Code and a recommended check-sheet has been developed using these examples (Appendix 9).

4.2.1. Minimum requirements for medical certificates

In many countries divers, whether in the employment of institutions or working as students or volunteers, must have a medical examination at least at the start of employment and annually thereafter. This must be at least of a level equivalent to that set out in the Class II medical certificate (4.2.2.; Appendix 9). It is strongly recommended that this should be adopted as the basic medical requirement by all establishments working to this Code of Practice.

4.2.2. Levels of medical certification (Appendix 9)

(a) **Class II.** This is the general medical certificate recommended for scientific diving under this Code of Practice. It should be used to medically certify divers for all diving except that associated with the Class I certificate. The period of validity of the Class II medical certificate is 12 calendar months.

(b) **Class I.** This is a specialized medical certificate recommended for use in evaluating medical fitness for saturation or exceptional exposure decompression diving. The Class I certificate may be used in place of a Class II certificate to medically certify a diver. However, because of the added hazards of the radiological tests involved in having to otherwise take two closely spaced radiological examinations, it is strongly discouraged as a general practice. The period of validity of the Class I medical certificate is 6 calendar months. At the end of this period, the Class I reverts to a Class II certificate for 6 calendar months.

4.2.3. Other certificates

There are a number of different commercial, military and sports diving medical standards used nationally and internationally. When a new scientific diver joins an organization holding such a medical certificate, the standard should be consulted to determine if it correlates as equivalent to the Class I or Class II medical standard recommended by this Code. It is recommended that equivalent medical certificates should be recognized, and repeat medical examinations be avoided.

4.2.4. Decompression training and medical records

Divers must be thoroughly instructed in the dangers of decompression sickness, the use of no-decompression limits and, when relevant, the conduct of decompression dives (4.11;11). Recent research in decompression theory suggests that the tissue models used in computing existing air diving tables are not accurate. One implication of this research is that divers should be conservative when using the tables. A second is that information ought to be collected on the incidence of decompression sickness and aseptic bone necrosis among divers operating with these tables, or with decompression computers, in order to validate empirically the tables and document the risks their use entails.

It is strongly recommended that similar programmes be set up for divers operating with other major tables in use (French tables, US Navy tables, Defence and Civil Institute of Environmental Medicine tables [Canada], etc.), and that examining physicians be made aware of this service.

Medical Officers employed by an establishment to conduct the medical evaluation of divers and to treat divers' injuries should be apprised of the nature and treatment of decompression sickness and bone necrosis. Incidents of decompression sickness should be fully documented with medical records and dive record sheets (4.7). Post-treatment: the long-term effects of incidents should be monitored, including any possible onset of aseptic bone necrosis.

4.2.5. Gender factors in diving

Women and men have some differing physiological parameters in diving, therefore their medical certification requires slightly different emphasis. For example, a woman's subcutaneous fat deposits may tend to increase the risk of hyperthermia as well as of decompression sickness, and diving during menstruation somewhat elevates susceptibility to decompression sickness, as may the use of birth control pills. Conversely, it has been suggested (Edmonds et al., 1981) that women are liable to hypothermia because of their lower body weight. These two conflicting hypotheses illustrate the lack of clear evidence in this matter and the doubtful basis for mandatory regulatory distinctions based upon gender.

Men with low subcutaneous fat levels are more susceptible to hypothermia, and facial hair can interfere with the seal of a facemask. Strength of both men and women should be evaluated on a task-specific basis and should be adequate for foreseen circumstances. Endurance varies significantly among both individual men and women and can be markedly influenced by fitness, training and skill. Culturally, there is evidence to suggest that men are more likely to be cavalier about diving safety, more apt to abuse alcohol or dive when fatigued or not up to standard physically. Here again there is marked variance among individuals.

Medical check-lists incorporate the more significant of these variables. It is advisable that the Medical Officer employed by the establishment to conduct the medical evaluation of divers should know of these differences and be able to advise divers in these matters. Additionally, the Chief Diver/Diving Officer should similarly know and be able to evaluate the fitness of individuals for diving activity.

4.2.6. Pregnancy and diving

Some countries may ban employed women divers from diving during pregnancy, while others make no such restrictions. Where there is legislation in these matters, it should be given priority. Where no such legislation exists, the following guidelines are applicable, and have been prepared by a group of women scientific divers (Unpublished report prepared for the British Natural Environment Research Council Safety Officer, 1984).

Normal standards of health and fitness required for diving must be upheld. Consequently, certain temporary medical problems, e.g. elevated blood pressure, toxaemia, severe nausea and sickness, varicose veins, vertigo, etc. arising during pregnancy, or as a result of menstrual or hormonal disturbance, however caused, should be regarded as probable contra-indications to diving depending on their severity. Symptoms must be assessed individually by a competent medical officer. Certification of fitness for diving should therefore normally be obtained if such problems arise and persist, particularly if medication is being taken.

There is some evidence that women are naturally slightly more susceptible to decompression problems (Edmonds, et al., 1981). It may be prudent therefore, in planning decompression schedules to allow a wider margin of safety than usual in interpreting maximum depth and times required in no-stop and stage decompression diving.

Particular attention should be focused on potential hazards associated with diving during pregnancy, in addition to other health problems identified. Any abnormality of pregnancy, e.g. Placenta praevia, blood loss, threatened miscarriage, etc. should be regarded as a disqualifier for diving.

Diving may possibly incur hazards both for the unborn child and for a pregnant woman herself, even when there is no existing health problem (Bolton, 1980; Edmonds et al., 1981; Rankin, et al., 1980). The evidence is not statistically clear either for or against this proposition and the woman diver must be encouraged to make her own decision within the limits of existing legislation or rules. Women divers should keep a careful check on their menstrual cycle so that pregnancy, if suspected, can be confirmed as early as possible. This is in their own and in their colleagues' interests. The most critical time for the foetus is possibly during the first trimester, when foetal development could be placed at risk (Bolton, 1980). For this reason, women planning conception may be wise to restrict diving in order to cover the period when pregnancy cannot be detected.

In late pregnancy (third trimester), mental alertness is often deleteriously affected so that responsibilities and decision-making, especially in emergencies, could be seriously diminished.

A woman's physical shape and condition in the third trimester are such that they render her more easily fatigued and less agile. These factors are likely to affect her safety and stamina in diving, particularly in carrying heavy gear which she should not be doing at this time. In practice, individuals may vary from feeling quite fit throughout pregnancy to being totally incapacitated even for the mildest levels of physical work, especially in the third trimester.

Under normal circumstances therefore, a woman should not undertake diving duties during the third trimester as her condition may affect the safety of both herself and her colleagues.

In conclusion, if pregnancy is suspected or confirmed, diving should be restricted:

1. First trimester: Maximum depth of 20 m, and a duration of half the no-stop time (limit of no decompression stop diving) of the decompression tables (Section 11).
2. Second trimester: Maximum depth of 20 m, and a maximum duration 5 minutes less than the no-stop time.
3. Third trimester: No diving.

4.2.7. Confidentiality of medical reports

The detailed medical report of a doctor examining a diver should be treated as confidential, and the doctor should report to the employer whether the diver is or is not fit for diving. However, it is in the interests of safety that the Chief Diver/Diving Officer be informed that a diver is suffering from a particular condition, before the diver takes part in diving operations, if the medical officer considers that this might in any way limit the type of diving operations for which the diver is fit.

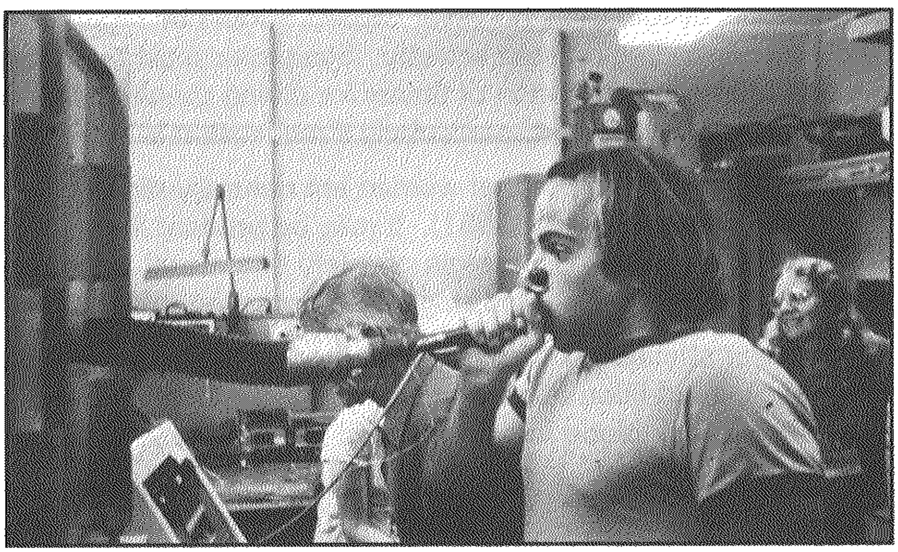


Photo 2: Periodical medical exams play an important role in helping to ensure diver health and safety. *Photo: G. Stanton.*

4.3. Fitness

In establishments where personnel dive regularly, the diving itself will keep them physically fit; special attention need only be paid to colds or other passing ailments. Where personnel dive only from time to time there will be a problem of maintaining adequate physical fitness. Although fitness may not apparently be needed to perform planned tasks, an emergency can produce a situation where fitness, quick reflexes and strength may make the difference between safety or a serious accident. In preparation for diving operations the senior diver in charge should consider the fitness of personnel involved, taking into account the recent diving operations or sporting activities which may have helped to maintain fitness. If personnel are obviously unfit they should be given a series of swimming and snorkeling exercises in the weeks preceding field work. Regular aquatic exercise contributes to diving safety. Divers should be able to complete an 800 m snorkel swim with fins in 16 minutes.

4.4. Swimming pool and sea training schedules

Recent surveys of establishments where scientific diving is carried out have shown that the diving techniques used are almost exclusively those of scuba. The minimum training standard accepted by Diving Officers is generally that of a mid-level sport diving certification such as the NAUI Level IV, BSAC Advanced Diver and CMAS 3-star. However, it is recognized that a newly trained diver usually requires 10-30 working dives after completing certification before they can be considered fully trained for scientific work. Training schedules are established in codes published by the AAUS and CAUS.

Additionally, in some countries (Canada and the US) divers are allowed to enter diving programmes at a lower level of certification (NAUI Level II) as 'divers-in-training', and gain experience through on-the-job training for eventual certification as scientific divers (2.9). This method allows divers to be fully trained for task-specific skills in fewer dives and consequently to be certified in fewer dives.

Initial instruction of divers may be accomplished within the establishment or by sending them to a recognized club, dive store or diving school.

In the training of scientific divers it is important that the discipline of thinking and working while diving should be introduced early on. This should be done in parallel with the tests of ability to swim, cope with diving equipment and maintain safety, which are typical of sports diving training. This work training should be of an introductory or familiarization nature, and not so arduous that it interferes with learning to dive. Work familiarization should concentrate primarily on the following range of tasks:

1. Navigation, search and recovery, underwater rope-work, dive-site selection, scientific dive planning and team-work.

A secondary range of work familiarization could include:

2. Sample collecting methods, data gathering techniques, common biota behavior, installation of scientific apparatus, site location and relocation, small boat operations and knowledge of government and legal requirements when diving at work.

Dive training should be conducted both in the pool or sheltered waters and in open water. The intensity of training may be increased by simulating adverse conditions in protected water, such as low light or reduced visibility, or by training under actual open water conditions but in a highly supervised and controlled setting.

Before any open water operations involving new equipment or untried methods or techniques are used, the personnel involved should train with the equipment in a pool or under sheltered conditions. Similarly, proposed work in extreme conditions such as under ice, rough seas or fast currents (8.2) should be preceded by appropriate training and practice in such conditions.

There should be thorough training in the use of adjustable buoyancy systems where they are being used.

4.5. Theoretical knowledge

Standards of theoretical knowledge must be at least to sports diving certification levels for scuba training (NAUI Level IV, CMAS 3-Star), preferably supplemented by additional reading. Theoretical knowledge related to equipment maintenance, navigation, first-aid and other specialized activities should be dealt with by instruction, reading and demonstrations. A written examination should be held as part of the training. Examinations designed to suit these specific requirements have been developed by a number of institutions and should be circulated internationally to the respective national scientific diving organizations and other interested bodies so that the levels may be compared, with a view to future standardization.

4.6. Qualification standards and working depths

The following standards relating experience to operational diving are strongly recommended:

1. No diver should be employed on a working dive, even as a trainee, until they have obtained a 'diver-in-training' certificate or equivalent. The first ten working dives should not be deeper than 20 m.
2. A 'diver-in-training' should not dive except when accompanied by a specifically authorized scientific diver.

4.7. Dive record sheets

Detailed dive records maintained by the Diving Officer provide the following:

1. Administrative records of time spent in training and work, for the purpose of assessing efficiency of effort, personnel and expenditure.
2. Record of training and experience of personnel.
3. Evidence in the case of an accident.
4. Basis for certification of training.
5. Evidence of safe diving for insurance purposes.
6. Medical evidence for collection of data on decompression tables.

Specimen dive record sheets are shown in Appendix 12.

4.8. Logbooks

Individual divers should keep a logbook as evidence of their experience and training and for reference in the case of accidents. The minimum record should consist of: dive-site, date, maximum depth reached by the diver, name of diver, name of diving companion, name of dive supervisor, decompression schedule used, repeat tables used if any, outline of work, and sufficient data on start and surfacing times, and time of leaving the bottom, such that the dive profile can be checked against the decompression procedures carried out. In addition, the true clock time of surfacing <u>must</u> be recorded so that surface intervals can be calculated before making the next dive.

It is highly recommended that the diver's logbook also contain a photograph, medical endorsements annually and certificates of training. A number of standard logbooks are available and some styles are included in this Code (Appendix 12).

To avoid loss of information, it is recommended as a general practice where divers are operating in inclement conditions, that dive records be kept on-site in a 'wet-log,' preferably made of waterproof paper, and daily transferred to the permanent log.

4.9. In-date qualifications and work-up dives

Scientists often do not dive regularly, and a check must be maintained on their readiness for working diving. The following two systems have been used successfully, and may be combined as suggested below.

4.9.1. In-date readiness system

This system assumes that a diver who has dived within a set period is fit and ready for working diving. The practice is liable to abuse, and personnel may carry out token dives which do not really maintain training. It seems preferable to set a time limit of one month within which personnel retain readiness for working diving, and to state that the qualifying dive must itself be a working dive, or a practice dive to at least 20 m for 20 minutes with a simulated work task. Except in coastal institutes, most divers will probably lapse from in-date readiness, and work-up dives will be necessary before projects.

4.9.2. Work-up dives

If a diver lapses from in-date readiness it does not affect the diver's basic qualification. The sequence of work-up dives required to give working preparedness depends on the depth of work and the time lapse since the last dive. An outline of a recommended schedule is given in Table 4-1.

Table 4-1. Recommended schedule of work-up dives for various working depths after a break from active diving.

Time Lapse	Working Depth		
	10 m	10-20 m	over 30 m
1 - 2 Months	10 min	20 min	20 min 30 min
2 - 12 Months	10 min 20 m	10 min 20 m Working Depth	10 min 30 min Working Depth
Over 12 Months	Pool Test# 10 min	Pool Test# 10 min 20 min Working Depth	* Pool Test# 10 min 2 x 20 min 2 x 30 min Working Depth

* In some countries this requires complete re-certification.
\# Open water in very sheltered conditions may be suitable for these tests in a warm climate.

Dives should be considered purely as training, but may involve light work which can be easily abandoned in the interests of safety. Dives should be at least 20 minutes in duration, unless excessive decompression time would be incurred. If an individual fails in the task or seems unhappy during work-up dives, the Chief Diver/Diving Officer should extend the work-up period or drop the diver from the team. The briefer work-up schedules may be included in the first day or so of the project if the divers are generally fit, but the longer schedules should be started well in advance of work to allow for unforeseen problems and to regain fitness. Work-up dives appear to increase decompression safety by lessening the risk of bends.

The importance of the 'in-date' concept and the necessity for work-up dives cannot be stressed too strongly. They are key factors contributing to the overall safety of diving operations carried out by an establishment, and Directors, Heads of Departments and Chief Scientists, should always be aware of the need for diving personnel to maintain their state of readiness and allow sufficient time and funds for them to do so.

4.10. Team compatibility

Where projects involve the use of specialized equipment, or work in extreme or potentially hazardous conditions, an important factor of safety is the degree of team-work. In these circumstances the known or recorded qualifications of team members are not in themselves a guarantee of safety; the divers should be trained together frequently until the required degree of cohesion and mutual trust is developed. If diving is to be carried out in pairs, the Chief Diver/Dive Supervisor may establish fixed pairing for the work as it becomes clear which divers work best together. If a more general degree of team unity is required, diving pairs may be switched around, but it becomes important to drop from the team any individual who turns out to be incompatible with more than one or two of the other divers. This requires a great deal of discretion on the part of the Diving Officer or Chief Diver.

4.11. Compression chamber dry dives

On the first occasion of extensive work planned below 30 m it is advisable that divers should be exposed to the proposed working depth in a compression chamber where this is possible. This enables the project organizer to assess the ability of the divers to perform complex tasks while suffering from narcosis. Furthermore, the decompression phase may reveal personnel who are exceptionally liable to bends. Where extensive deep diving is carried out supported by an on-site compression chamber, it is advisable that several members of the team should be fully trained in chamber operation at a recognized school, since if only one operator were trained, there would be a dangerous situation if that person suffered a bend (4.2.4; 11).

4.12. Recognition of other training qualifications

The CMAS has produced an international comparison of certificates and qualifications issued by sports diving certifying agencies, with equivalence of standards (Appendix 7). Using this system of comparison, the CMAS Scientific Committee has developed a scientific diver certification (Brevet) based on the sports diving certifying criteria in different countries at the 3-Star level. The application form can be copied from Appendix 10.

As well, in several countries (e.g. Canada, the USA, the UK, South Africa and the Federal Republic of Germany) organizations have been founded to establish and maintain national standards for scientific diving. A number of authoritative national standards are now available. Three of these (Canadian, British, American, 2.4) have been primarily consulted in developing the training criteria set down in this Code of Practice (Appendix 13).

Institutes are recommended to certify their divers to the standards of this Code of Practice as a minimum international standard and to qualify divers to a higher standard in specific skills where necessary because of national or regional diving practices. In countries where no national or regional training standards for scientific diving have been set, establishments may supplement the minimum requirements of this Code with higher standards based on sports diving training programmes or their recognized CMAS equivalents, or commercial standards in mixed gas diving.

Full recognition should be given to training qualifications of military and commercial diving schools. In view of the lack of accepted certificates of working experience, Diving Officers should inspect log books of personnel from other institutions or from abroad. Chief Divers/Diving Officers should bear in mind that a highly trained diver from a foreign country may have a totally different range of practical experience and skill from that required locally (1.2; 1.3; 2.7).

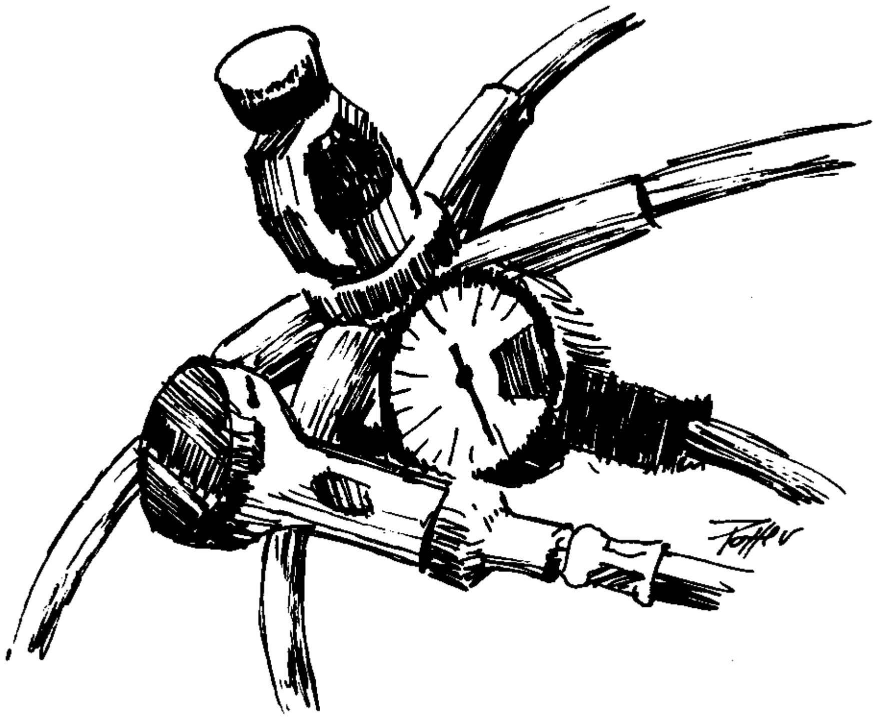
4.13. Mixed-gas training

Scientific work may require the use of mixed-gas breathing equipment (7) for specific work-related purposes, for example, to diminish inert gas narcosis, to give increased endurance, to minimize acoustic noise or to eliminate the visual or mechanical disturbance caused by exhausted bubbles. In view of the complexity of the equipment and the need for an exceptionally high standard of maintenance and adjustment of the sets, potential users should attend an appropriate and recognized training course.

Commercial diving schools, military training schools, and in some cases government agencies (e.g. the National Oceanic and Atmospheric Administration Diving Unit in the USA offers mixed gas training) are potential sources of mixed gas training courses for scientific diving programmes and should be consulted as a resource.

Before use of non-scuba breathing systems, a check should be made of government regulations and professional and industry standards covering use of oxygen and mixed-gas systems, closed-circuit and semi-closed circuit diving equipment and training for use of these systems and equipment in the country of the potential user. Constant training must be maintained when using mixed-gas equipment, and a program of continuing training should be developed based on these requirements and the recommendations of the training agency and the equipment manufacturer.

A number of authoritative standards for mixed-gas diving have been developed (Appendix 2).



SECTION 5. EQUIPMENT MAINTENANCE

5.1. Introduction

All diving equipment used under the auspices of a research organization must, regardless of ownership, be inspected and serviced by an individual or facility approved by the Diving Control Board/Diving Officer. The Chief Diver/Diving Officer is responsible for restricting or removing from service any diving equipment that does not conform to the standards of the Diving Control Board. The Diving Officer is also responsible for evaluating equipment maintenance programmes and assuring that a record of all inspections and equipment overhauls is forwarded to the Diving Control Board.

All scientific divers are expected to perform a basic inspection of their own and their teammate's equipment prior to each dive (6.1.2). All equipment must be in good serviceable condition; deficiencies demand the cancellation or termination of the dive. All equipment problems must be brought to the attention of the Diving Supervisor. Each diver is responsible for the care of any items of equipment that are issued to him or her.

5.2. Statutory requirements

In many countries there are statutory requirements that apply to the equipment used by all divers, scientific as well as sports and commercial. Normally such regulations involve the testing and inspection of high pressure cylinders, valves, regulators and pressure (contents and depth) gauges. It is imperative that all such statutory requirements be met. A complete list of all maintenance items and periods, for all diving and support equipment used, should be part of the institution's code of practice or internal safety rules.

5.3. Technical and maintenance procedures

All inspections and overhauls referred to in this section, except those suggested for the diver, must be performed by an individual or facility approved by the Diving Control Board/Diving Officer. All equipment that fails to function in a satisfactory fashion or that is found lacking during a diver's check must be tagged and removed from service until repaired. All diving gear that is fit for subsequent work must be properly rinsed or washed, dried if possible, and stowed as soon as possible after use.

5.3.1. Scuba tanks and other refillable gas cylinders

High pressure cylinders should be inspected for external damage before and after each dive, be visually inspected internally prior to first use and at least every year thereafter and hydrostatically tested every five years. Most manuals and codes of practices of national federations specify inspection methodology.

In countries where compressed air cylinders are required by statute or custom to be painted in a distinctive color or manner, all cylinders used in scientific work should be so painted. Care should be taken that the painting process does not heat the tank above 200°C and thus weaken the cylinder.

If cylinders are to be stored for some time, they should be internally inspected to assure that there is no water in them. Cylinders should be filled to 5-10 ATM and stored in an upright position whenever possible.

5.3.2. Scuba regulators and submersible pressure gauges

Regulators and submersible pressure gauges must be functionally tested by their user prior to each diving session. They should be disassembled, inspected and re-adjusted twice yearly, more frequently if used for deep or unusual diving operations or if they exhibit any signs of malfunction such as increased breathing difficulty. All hoses must be inspected often and silicone spray or grease (not petroleum) should be applied to the dried, first stage water chamber of the regulator from time to time. Breathing gas pressure gauges should be accurate to within 5% of the actual pressure over their entire range. 'Zero-errors,' which are variances from a proper reading when the gauge should be reading zero, are the most critical and should be marked on the gauge face.

5.3.3. Depth indicators (gauges)

Non-capillary depth gauges (including decompression computers), should be tested prior to first use, at six month intervals and at any time that they appear to disagree by more than 2% with another gauge or a known depth. Gauges should be tested against a master instrument of 0.25% accuracy or a measured shot- (down) line. No gauge should at any time read any shallower than the actual depth. Gauges should be tested at least at depths of 6 m and 45 m. At 6 m, new gauges should not read more than 6 m plus 1% of the full scale, but used gauges may have twice this error. At 45 m new gauges must read no more than 45 m plus 3% of the full scale and used gauges must be within 5% of the full scale. Gauges that do not meet these performance specifications must be repaired and retested or discarded. A calibration tag indicating gauge variations at selected depths should be carried by the diver in an accessible location. Variations can also be marked on the face of the gauge.

Depth gauges should not be transported in the baggage compartment of an airplane or in an unpressurized aircraft since the low pressure may damage the instrument. Small, air-tight containers are available to alleviate this problem.

5.3.4. Compressors and storage banks

Compressors should have the air intake located in an area where the atmosphere is clean (6.1.3). Intakes must not be exposed to the exhaust of internal combustion engines or air that is contaminated by any other source. The intake must be equipped with a suitable dust filter. Commercial filter material should be used rather than improvised materials designed for other purposes such as towels that have recently begun to be treated with deodorant chemicals, which could be harmful to the divers if inhaled. If the intake is extended, it must be protected to prevent the entry of excessive amounts of moisture. The total length must never exceed the manufacturer's specification. Appropriate filters and separators must be incorporated into the compressor and filling system in order to remove moisture, oil mist, particulate matter and odors. All compressors must be operated in accordance with the manufacturer's instructions and specifications. All pressure fittings, hoses, plumbing and pressure system components should have a maximum burst pressure at least four times the planned maximum working pressure. Slow-opening shut-off valves should be used to control air lines that carry pressures in excess of 30 ATM.

When a compressor is used to supply a diver in the water through a hose, the system should include a volume tank with a check valve on the inlet side, a pressure relief valve and a drain valve.

Air quality should be analyzed every six months or 25 hours of operation, whichever comes first, by means of samples taken at the connection to the distribution system, to ensure purity for breathing in accordance with local regulations or statutes. Suggested air quality standards are: Nitrogen - 79%; Oxygen - 21+0.05%; Carbon Monoxide - less than 20 ppm; Carbon Dioxide - less than 1000 ppm; oil mist - less than 1 mg/m3; no detectable gross moisture, dust or particulates and no noxious or pronounced odor. See Table 6-1 for a comparison of some accepted technical standards.

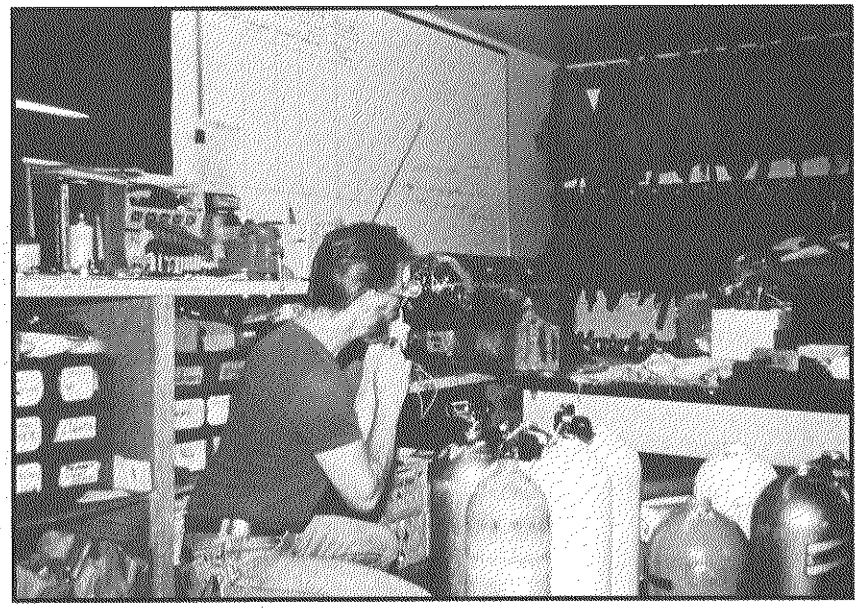


Photo 3: Proper maintenance, storage, and labeling of cylinders, tanks, and other equipment should be a major priority. *Photo: G. Stanton.*

Compressed gas storage cylinders should be stored in a ventilated area and protected from excessive heat. They should be secured from falling and have shut-off valves recessed into the cylinder or protected by a cap except when in use or when manifolded. Cylinders should be inspected and tested as outlined in Section 5.3.1.

5.3.5. Underwater tools

Underwater tools, such as hand-held electric power tools or other powered equipment, must be approved by the Diving Control Board/Diving Officer. When supplied with power from the surface they must be disconnected from surface power before being place into or removed from the water. Power must not be turned on until requested by the diver.

5.3.6. Special equipment

Special equipment requirements and regulations shall be promulgated as required (10).

5.4. Records of maintenance checks, tests and repairs

Maintenance logs or records must be kept for all equipment that is subject to inspection and service. These records must be available for inspection by the divers or the authorities. Divers are entitled to copies of records for any equipment that they have signed out. The Diving or Equipment Officer is entitled to inspect records of all equipment that is brought into a project under his/her direction or authority. Statutory bodies may require documentation of ownership and other records of some types of diving equipment. Each equipment modification, repair, test, calibration, maintenance and sometimes use, should be logged. A log should include the date, nature of the work performed, serial number and nomenclature of the item and the name of the individual or facility performing the work. Items for which such records should be kept include: compressors, scuba regulators and cylinders, gas storage cylinders, pressure and depth gauges, scuba cylinder valves, ABLJ's, dry suits and analytical instruments used for service or inspections of diving equipment or breathing gases.

SECTION 6. SAFETY

6.1. Pre-dive safety

Prior to the divers assembling at the dive-site, several matters have to be considered that are important to safety.

6.1.1. Dive planning

Detailed recommendations for the conduct of diving operations in certain special conditions are given in Section 8. These must be referred to and combined with the general recommendations in this Section as appropriate.

The dive planning of any underwater project must take into account scientific objectives and psychological and practical limitations. Therefore realistic planning is best carried out by people with both scientific and diving training. When the Chief Scientist has no diving experience it is essential that the Institute Diving Officer be consulted about, and the Chief Diver involved in, the detailed planning of operations. Their responsibility shall be to maintain the highest possible standards of safety.

Efficiency in underwater work depends upon making the most effective use of the limited number of underwater man-hours per day. The right research questions must be asked and means devised of collecting data to answer these questions quickly and accurately. The scientific problem must be extremely well defined at different investigative levels so that changes in planned dive-sites or dive profile/times can be made in response to data already gathered. Very few project diving plans ever are carried out exactly as conceived prior to the beginning of the project; the success of a project often resides in the adaptability of the planning. In addition, equipment which is not necessary to the efficient conduct of the diving such as complex camera and tape-recorder systems and their ancillaries can divert attention from the more basic but important diving gear. No more equipment should be employed than is necessary. The equipment mix that is deployed underwater should be familiar to the divers through prior training.

Diving and scientific equipment check lists, which should be waterproof, must be used at the operational base and if necessary on the small boat used for surface cover. A diving safety box, including oxygen, should be carried in the small boat (6.2.5). While every effort should be made to provide self-sufficiency in safety and back-up facilities, the following information should be held at the operational base and on the cover boat, which in the case of an emergency might have to return to shore and begin immediate aid at some point other than the operational base. The following information should be immediately available in the case of an emergency:

1. Name, address of the nearest doctor, ambulance facility and hospital.
2. Location and telephone number of the nearest compression chamber.
3. Location and contact procedure for helicopter rescue if relevant.
4. Telephone number of local coastguards, marine rescue units or police.
5. A map showing the exact position of the above rescue and medical facilities and the position of telephones nearest to shore access points in relation to the diving area so that any member

of the diving party will be able to get help in the shortest possible time. This becomes more important in more remote areas and where shortwave radio use is not common.
6. A list of available radio frequencies and information about their use such as when they are monitored, etc. which can be raised by the radio equipment carried by the diving party.

Daily information from appropriate weather forecasts should be obtained. Land, shipping or inshore fishermen's forecasts should be used as appropriate for the area. Special note should be made of changes of expected weather that might affect the safety of operations, e.g. wind strength or direction change and fog. Information on tidal streams and currents should be sought from marine charts, tidal atlases and pilots. These should be supplemented, when appropriate, by local information from seamen and fishermen.

A first-aid kit should be available to the diving team, and two members of the team should be qualified to use it. All divers should be trained in expired air resuscitation (mouth-to-mouth) and external cardiac massage. In remote locations a full medical kit should be carried, and at least one person should be trained to paramedic standards.

6.1.2. Personal equipment maintenance (See also Section 5.1)

Each diver is ultimately responsible for the maintenance of his/her own diving equipment, which if it is not personally owned should be assigned on a permanent, seasonal or project basis and not re-assigned from the equipment store daily or weekly. The longer the period that a diver has to become used to personal equipment the better, in that its peculiarities can be assessed and either compensated for or taken advantage of during use. Additionally, if a diver is assigned gear for a considerable period of time, the gear tends to get looked after better.

All diving equipment shall be inspected by the diver for proper functioning at the beginning and end of each diving day. Equipment to be inspected shall include, but not be limited to:

1. All straps, hoses and soft items (rubber, nylon, etc.) for cracks, dry rot and/or other signs of deterioration.
2. Wet or variable volume dry suits for tears, zipper, seals, etc.
3. Scuba cylinders for damage, proper pressure and valves.
4. Regulators, hoses, fittings, accessories, mouthpiece, etc. for tightness, cracking, etc.
5. Weight belts and buckles.
6. Buoyancy control devices and all mechanisms that could jam up with salt including direct feeds.
7. Diving knives, inflatable buoys, ropes and all snap clips.
8. Any accessory equipment such as dive lights, cameras, data recording sheets, etc.

Every reasonable effort shall be made to prevent damage to equipment during the diving operation.

Any malfunctioning item shall be individually tagged giving the name of the user (or the person who noticed the malfunction), date and nature of the malfunction. Tagged equipment shall be brought to the attention of the Diving Officer or Equipment Officer at the earliest opportunity.

6.1.3. Purity of air and gas supply

Compressed air shall only be obtained from sources known to conform to approved national standards and in the absence of a national standard to a standard recognized elsewhere (Table 6-1).

Table 6-1. Air Purity Standards

	United States Navy	Canadian Standards Assoc.	University of California Dept. of Marine Resources	British Standards Assoc. (BS 4001)	British Sub-Aqua Club	Canadian Assoc. for U/W Science
Nitrogen	As atmospheric air - 79%	As atmospheric air	As atmospheric air	------	As atmospheric air	
Oxygen	20-21%	--------	As atmospheric air	------	21% ± 0.5%	
Carbon Dioxide	Not more than 0.1%	0.05% (500 ppm)	0.03% (300 ppm)	500 ppm (300 ppm)	0.03%	500 ppm
Carbon Monoxide	20 ppm	10 ppm	*20 ppm	10 ppm	5 ppm	5 ppm
Oil	130 micro-grams per litre	1 mg per M^3 droplets of oil	Free from M^3	1 mg per M^3	1 mg per M^3	1 mg per
Water	Free of gross moisture	As dry as possible. Should not condense	Free from droplets of water	As dry as possible and not give rise to condensation at temperatures above 40°F	0.02 grammes M^3 at N.T.P.	
Solid, Particles Dust, etc	Free of gross dust and foreign matter	Free from dust, dirt and metallic particles	Lack of residue on a Whatman 40 filter after passing 5000cc of air**	Free from dust, dirt or metallic particles	Lack of residue on a Whatman 40 filter after passing 5000cc of air**	
Odour and Taste	------	Free from all odious taste or irritating substances	Absence of odours and vapours	Free from odour and toxic or irritating ingredients	Freedom from both	Free from odour
Nitrogen Dioxide & Nitrous Oxide	------	Covered by above	------	------	NIL (under 1 ppm)	0.2 ppm

* Not more than 10 ppm for decompression dives
** Whatman 40 filter, rated as fast and of mean pore size 3.4 to 5 microns

If compressors are used in the field, frequent attention must be paid to the siting of the air intake in relation to fumes and smoke, not only from the compressor, but also from vehicles, boats and houses in the vicinity. The intake is best fitted with a suitable length of flexible pipe to allow for changes of wind direction. Adequate cooling is essential in order to prevent contamination of air by overheating of lubricating oils. The nuisance caused by compressor noise in public places is to be borne in mind and minimized.

In a permanent laboratory site, times of compressing may need to be restricted according to wind direction in relation to sources of air pollution.

Precise adherence to manufacturer's recommendations in relation to filter replacement, maximum continuous running time and cooling is essential.

A compressor logbook shall be maintained to show running times, maintenance checks and filter changes. A running-hour meter is advisable (5.3.4).

The use of 'breathalyser'-type tubes for gas analysis is strongly recommended for carbon dioxide and carbon monoxide, nitrogen dioxide and nitrous oxide. Further checks for hydrocarbon contamination are given in Stubbs and Roberts (1970).

Periodic analyses should be made of the gas from cylinders filled before and after periods of maximum continuous running, and before and after filter changes. A complete analysis shall be made in the event of an accident, or if a diver complains of headache or respiratory distress during or after a dive.

Particular care to prevent contamination of breathing apparatus by dirt, oil and grease is essential after repairs.

6.1.4. Fire risk

The atmosphere in compression chambers frequently contains a higher partial pressure of oxygen than normal air at one atmosphere, and therefore is capable of sustaining rapid and violent combustion. Several fatal accidents have occurred as the result of fire in compression chambers. Most of the causes can be eliminated in the design of the chamber, but all chamber operators should be aware of the risk and ensure that combustible materials and sources of sparks or ignition are not taken into compression chambers. The deliberate use of high oxygen partial pressure to speed decompression or improve therapeutic treatment increases the potential fire risk.

Experiments have been conducted with a variety of chemical, gas and foam fire extinguishing systems in high pressure oxygen-rich environments, but most systems are either relatively ineffective, or produce toxic side effects. At present water is the best all-around extinguisher and is best applied as a steady spray (Shilling et al., 1976).

General rules for providing fire safety in a hyperbaric chamber:

1. Oxygen concentration and/or partial pressure should be as low as possible, preferably within the region of non-combustion. It is essential to use an overboard dump system where pure oxygen is breathed by mask in a chamber.
2. Ignition sources must be eliminated.
3. Combustibles should be minimized, with the complete exclusion of flammable liquids and gases, oil and grease.
4. If combustible materials must be employed, their type, quantity and arrangement in the chamber must be carefully controlled. Potentially combustible materials should be chemically

treated if possible.
5. Fire walls and other containment techniques should be used to isolate potential high-risk fire zones.
6. A fixed fire-extinguishing system should incorporate smoke detectors and both manual and automatic switches; it should provide rapid and sufficient agent discharge.

Other risks of fire on a scientific diving project is a normal consequence of having items like Neoprene, hydrocarbon fuels, alcohol and various solvents and paints, etc. present for the normal progress of the project. These risks are not particular to the diving but to the materials. High oxygen partial pressures alone distinguish the diving related fire risk.

6.1.5. Food and drink

In most circumstances normal daily food and fluid intake is left to individual discretion. At the beginning of a diving day, however, it is a good idea to eat a carbohydrate- and fat-rich breakfast for long-term energy supply. In the middle of the day high-energy foods which are sugar or calorie rich that can be converted rapidly into energy to get through the rest of the working day are best followed by a snack of the same high-energy transfer food later in the afternoon especially if it is a long, arduous day. High-protein foods will be best used by the body in terms of overall food type during the course of a working scientific diving project.

Where diving is to be conducted in remote areas necessitating the issue of rations, a balanced adequate diet must be planned and adequate fluid intake ensured. Medical and dietary advice should be sought before leaving for such areas.

Salt supplements may be issued in hot climates if in accordance with local practice and medical advice.

Diving should be avoided for 2 hours following a heavy meal. Regular light meals should be taken during the day's diving operations. Liquid intake must always be maintained at least to normal levels, as it is dangerous to become dehydrated prior to dives that may require decompression (11).

6.1.6. Alcohol

Alcohol may increase the susceptibility to decompression sickness and may enhance heat loss in cold water exposure. In a diver who is slightly hypothermic, alcohol may make the condition more serious.

Alcoholic drinks must not be taken until after normal diving and follow-up operations for the day are over.

Alcoholic drinks should be consumed only in moderation during the course of prolonged diving operations.

Alcoholic drinks are not recommended for 24 hours before diving operations to depths in excess of 30 m.

Diving with a hangover is dangerous.

6.1.7. Sleep and fatigue

Adequate rest and sleep will be defined by the requirements of the diving program and the fitness of the diving personnel. During diving, fatigue is dangerous, and a tired diver should not be permitted to dive. Sleep and rest periods should be built into the planning of a project as different scientific work requires different levels of follow-on work in the evening. Diving geologists, for instance, usually only require a limited time for recording and analyzing data after the diving and equipment care is complete; whereas the day of a diving zoologist may only be beginning at the end of the diving and equipment care, with numerous samples to preserve and classify. The nature of the specimen taking and the scientific follow-on work must be taken into account by the Diving Officer and Chief Scientist in developing project plans.

6.1.8. Cold (See also Sections 8.2.2 and 8.2.3)

A cold diver is liable to rapid fatigue and to errors of judgement. He/she will be less able to cope with emergencies, or with diving tasks, and will be less able to concentrate. The combination of fatigue and cold should be avoided at all costs in diving operations. If this is not possible abandonment or serious revision of the diving program must be considered by the Chief Diver/Dive Supervisor if accidents are to be avoided. A project plan which ignores divers' comfort, especially with respect to cold, will inevitably result in bad morale and less-than-enthusiastic divers. If the cold cannot be mitigated, it must be seen by the divers to be a fundamental concern of the Dive Supervisor in order to promote their co-operation and enthusiasm for getting the work done.

Divers continue to lose heat from their bodies for some time after they get out of the water. This 'after-drop' in central body temperature can reach dangerous limits even if at the time of getting out of the water the diver was in a reasonable state. The problems of cold exposure can occur in all waters, tropical as well as polar.

Some of the following precautions can be taken to help minimize the problems of cold exposure:

1. No currently available diving suit provides completely adequate thermal protection in the water. A dry suit with suitable undergarments and air inflation is more effective than a Neoprene wet suit for diving work in temperate or sub-polar waters. Suit-heating systems are available but all have operational limitations and their use outside of saturation diving systems or surface demand systems is unusual.
2. The divers should keep warm before the dive. Shore and boat parties should be kept sufficiently warm to perform their duties.
3. Limit dive times to reduce the amount of heat loss. Plan dives to avoid frequent immersion and draining of wet suits in cold water if possible.
4. Reduce the extent of the after-drop by immersion in a hot bath or in a hot shower in the diving suit if this is at all possible. Keep in a warm environment out of the wind and if wearing a wet suit, wear a wind-proof cover over the wet suit at least on the trunk of the body.
5. Allow sufficient time between dives for the diver to rewarm if possible.
6. Provide hot drinks and a high daily calorie intake during cold-water diving. Alcoholic drinks must not be used to warm a cold diver.
7. Body temperature monitoring using either a rectal temperature probe or radiopill transducer in the intestinal tract should be considered for extensive cold-water diving operations. A drop of more than 2°C or a level of 35°C is dangerous.

6.1.9. Heat

Excessive heat is not a problem common to most scientific divers except in special circumstances (8.2.22; 8.2.28). In pool training where the water temperature may be well in excess of what the diver expects, as well as in the special circumstances, divers must take care not to become overheated and become hyperthermic. Muscular weakness, lack of concentration, slight trembling and the possibility of a sudden blackout similar to heatstroke are all to be avoided by wearing no warmer diving suits than are indicated by temperature conditions and by engaging in no activities which involve extended overexertion when diving in hot conditions. The effect of hot-water suit heating is difficult for the diver to judge; there is a tendency to request increased heat up to the point where adverse symptoms occur.

6.1.10. Drugs

(See bibliography and Undersea Biomedical Society).

Drugs fall into two categories: those administered for medical reasons and those which are addictive or mood altering.

Under no circumstances should personnel who use addictive or mood- altering drugs, or who have done so in the recent past be allowed to take part in any facet of a diving operation. Many of these drugs cause recurrent symptoms such as hallucinations or schizophrenic behaviour long after active use has ceased, and any potential member of a diving team who has had a drug abuse history must be cleared by a doctor competent to consider the physiological effects of diving on drug syndromes. This prohibition includes drugs referred to as both hard and soft; it is mandatory that the Diving Officer ensure that no drug-affected personnel are involved in any operations, and that no drugs are abused during the course of a diving operation.

In general, medical use of drugs during diving should be avoided where possible. At present, there is considerable concern that the effects of many drugs in common use may change in hyperbaric conditions. Drugs can influence diving safety in indirect ways, by impairing judgement and concentration, or by increasing a diver's susceptibility to narcosis and decompression sickness. Individuals under medical treatment are, in general, unlikely to be diving. Chief Divers/Diving Officers should be aware that individuals may be using drugs to control common problems such as seasickness, headaches, colds, etc. This common practice of self-medication may present a hazard, and the Diving Officer may wish to restrict their use, or restrict the diver's activities. Diving Officers should take medical advice in any case of doubt.

None of the practices listed below are encouraged but the most common forms of self-medication, with their problems, are listed for information.

1. **Seasickness.** Two groups of drugs are used:

a. **Hyoscine:** Drowsiness can occur, and if possible the drug should be tried initially during a period of non-diving seagoing. Proprietary drug name: Hyoscine.

b. **Antihistamines:** These are often more effective against motion sickness, but drowsiness is frequently marked. Considerable individual variation occurs in response to the drugs. They must be tried initially during a period of non-diving seagoing. Medical advice should be sought if a suitable drug is not found. Proprietary drug names: Cyclizine, Meclozine.

All other preparations are available on prescription or in a weakened form of these drugs. Consideration should be given by Diving Officers to restricting those on such drugs to diving support only.

2. **Headaches.** Pain-relieving drugs of all types should be avoided during diving. If pain is sufficiently severe to require drugs, then the diver is not fit to dive.

3. **Nasal catarrh.** Routine self-medication with nasal drips to facilitate ear-clearing, etc. may be medically hazardous. Such routine use should only be undertaken with medical supervision. The presence of any form of upper respiratory tract infection (common cold, sinusitis, middle ear infection, tonsillitis, sore throat, etc.) imposes an absolute ban on diving until the infection has cleared.

A nasal spray by the name of Afrin$_{TM}$ is used by some divers who anticipate possible blockages of the nasal passages or sinus. Divers should inform the Dive Marshal/Supervisor if they are using this spray.

6.2. On-dive safety

On-dive safety includes the time spent dressing or kitting up and preparing for the dive and the time spent following the dive during which the diving team leaves the vicinity of the water with all of their gear and specimens. Too often dive safety ignores all but actual dive and boat time. Many fatal and other accidents are known to have happened during preparation and winding up of a dive. It is the Diving Supervisor's responsibility to have full control of the operation from the time that the divers approach the water with their gear to completion of the diving operation, with all gear stowed, and the divers are no longer exposed to risk from normal working or boat-handling hazards.

6.2.1. Dive safety responsibility

No set of recommendations are suitable for all circumstances, and it must be the responsibility of the Chief Diver or Dive Marshal in the absence of the Diving Officer to decide if any usual safety measures are inappropriate in the local circumstances. This person should bear in mind the fact that weather, wind, sea state, tide and visibility above and below water can change during a dive.

6.2.2. Compatibility of equipment

Diving equipment varies considerably. As a general principle, equipment should be as compatible as possible within a group of scientific divers for operational as well as safety considerations.

Problems of compatibility do not occur with some types of equipment. They include the exact type of wet or dry suits being used, types of fins, snorkels, masks, standard weight belts, knives, depth gauges, watches and the make and model of ABLJ so long as the operation of the jackets are similar, e.g. direct feed and attached (emergency backup) regulator of the same pattern and operated on the same side of the jacket. Personal preferences or the available equipment, often personal equipment, will largely determine these items among the diving teams.

Other equipment is compatibility critical; that is, if there is not compatibility of systems and use, the degree of safety is lowered.

1. All first stages of regulators must be useable on all air bottles. In the event of a bottle or a regulator being found to be incompatible, they should be immediately removed from use. If a diver has a matched bottle/regulator pair that is incompatible, no other equipment can be matched and used in an emergency and the actual conduct of the operation is much more difficult, especially where multiple dives are being carried out without recharging, and tanks have to be swapped.
2. All direct feed connectors should be interchangeable so that no matter what regulator/direct

feed combination was being used, it could be connected to any ABLJ, lifting device or other equipment in the diving party. Buoyant emergency rescue lifts are thus possible among members of the diving party without recourse to the emergency air bottle. In the case of dry suits, all direct feed connectors must be able to supply air to all of the suits; incompatibility would be especially hazardous in the case of a bag dry suit with no natural buoyancy where air supply had run out and the diver's buddy could not supply air through the appropriate connector.

In some other cases, such as the similarity of regulators and the exact types of ABLJ, all divers should make practice or working dives using all of the equipment available to the party so that they are sufficiently familiar with it to operate it for another diver in the case of an emergency.

If more than one boat and engine combination are needed, it would be better if they are the same make so the divers will become more familiar with the general operation and will be more proficient with this equipment under extreme or hazardous conditions.

If electrical equipment is being used, the operating current and electrical connectors should be fully compatible.

6.2.3. Numbers of divers

Diving shall normally be conducted in pairs, one person being designated the dive leader for that dive. In a pair of experienced divers who have worked together to the extent of being able to anticipate each other's actions, private arrangements may be made regarding the management of the dive underwater, but the Dive Marshal should still indicate the official dive leader, at least for the record. In the event of divers losing contact with each other, they should surface after an agreed time interval has passed and re-establish contact.

The presence of a fully dressed standby diver with minimum decompression loading, ready to enter the water, is strongly recommended in all diving circumstances and is essential in those in which higher than normal risks are involved. These include:

1. Operations at depths greater than 30 m.
2. Diving on equipment or structures which are liable either to snag or entangle the diver, or to collapse.
3. Divers operating singly.

The standby diver shall be equipped with a tended line or surface buoy attached to sufficient line to enable descent to the maximum depth likely to be encountered in an emergency.

Circumstances may arise where the scientific objects of a project can best be achieved by divers operating singly rather than in pairs. There is no objection to this provided that overall safety is maintained. There must be adequate surface support. The use of a life-line, preferably incorporating a telephone, provides maximum safety. Alternatively, a line passing to a conspicuous surface buoy may be used. This must be attended by a surface cover. Diving alone without any form of line to the surface is very strongly discouraged.

Solo diving may only be undertaken at the discretion of the Chief Diver/Diving Officer and will be subject to the following:

1. There is no logical alternative method of completing the job.
2. Either a diver's float or a safety line must be used.
3. All possible safety and back-up support is provided, including a standby diver, fully kitted.

Depending on what statutory Regulations are in force, it may be necessary to obtain exemption in order to conduct solo diving or diving with a total team of less than a defined number of trained personnel, which varies from 2 to 4 divers present on-site.

If circumstances dictate three divers working together underwater, then the Dive Leader should give clear instructions to the other two about position and distance-keeping during free swimming. If four divers are involved, they should be organized as two pairs. These principles of organization should be followed if more than four divers are involved in any one job. An exception to this may occur during elaborate search techniques in which hand signals along a rope connecting a number of divers can be used by one Dive Leader to control a number of divers.

6.2.4. Diving from shore

One of the main problems faced by a project diving team making a shore dive is that very often there will be some distance between the nearest point that the land transport can approach the water and the shore entry into the water.

Care should be taken entering the water especially over rocks, and an agreed entry point chosen, bearing in mind changing conditions of tide level and wind.

Depending upon whether divers have snorkel cover, safety line or surface cover boat available, the swimming distance should be such that rescue is possible in the prevailing sea and weather conditions.

A shore party should be at a position where they can see the divers, or their bubbles or their buoys. They should be instructed in hand signals so that they will be able to communicate with the divers, and they should be given clear instructions on what to do in an emergency. They should be equipped with a rope for assisting the landing of divers and be trained in air resuscitation (8.2.7).

Beach dives sometimes involve long surface swims to and from the dive site.

6.2.5. Diving from small boats

Small boats that can be used in diver support include solid hull, semi-rigid and inflatables. A small boat is one that can be transported by the diving team either using a trailer or carrying it in one of the vehicles that the diving team is using for transport. In most cases, small boats that are likely to be used by divers have outboard engines and equipment is carried in special racks, in tie-down bags or boxes rather than being carried in holds.

Scientific and boat equipment that is not already fully waterproofed should be carried in at least splashproof bags or boxes as small diving boats are usually wet to work in and in addition expose the divers to the weather. All equipment that is not actually being used should be lashed down out of the way. Dive planning should take into account what equipment must be carried, in what order it is going to be used and thus how it is to be stowed efficiently. This will also determine the order of loading of a small boat, which often must be loaded quickly under difficult conditions.

The dive plan should include consideration of dive teams and the order of diving which will determine who sits where and who kits up first, etc. A sensible disposition of personnel in the boat during diving operations can greatly facilitate a diving operation, e.g. all diver entry at a rope ladder deployed at the port transom by the boatman, who acts as the diver recovery helper during that period of time that he has to shut down the engine. To do this he never has to leave the engine in case a rapid start-up and quick manoeuvering is necessary. If the divers and specimens are coming in everywhere, some equipment or specimens will almost certainly be damaged.

Trust local boatmen about local surface conditions and the weather.

There should be two serviceable boats on the working site if possible, and if not the single operating boat should carry a spare motor, however small. Because of rotating diving and boat teams, any member of the party might be the boatman in an emergency; therefore, each member of the diving team should develop and demonstrate ability in handling the boat under all normal operating circumstances and especially in close manoeuvering in bad conditions.

(See section 9 for boat particulars).

6.2.6. Diving from large boats

This subsection refers to larger boats that are dived from directly and yet are small enough to manoeuvre to pick up the divers. Diving from large ships (8.3.6) almost always involves the use of a small cover boat.

Boats in this class are usually small fishing or research boats up to about 20 m in length with a freeboard of no more than about 2 m to the deck space from which the divers are operating. Research boats almost always have detachable diving ladders which enable the divers to get back into the boat; temporary or permanent diving platforms are fitted on more highly engineered boats. Such platforms usually consist of a wooden or metal grid fitted at water level across the stern, with a fitted ladder that extends both above the platform and below water. Diving ladders should slope inward at the top, and there should be a substantial hand rail from the top of the ladder for about 1 m on the deck. Divers enter the water by jumping from the deck or platform; access to the boat is up a solid diver's ladder that is sufficiently long (1.8 m below water) to keep divers from inadvertently going under the hull as the boat rolls. Diver access and working space is almost always near the stern of the vessel where the deck space in less encumbered, more open and where the lowest freeboard is usually found.

The captain or boatman must demonstrate his ability to pick up divers by approaching an anchored buoy slowly from the down-current side and bringing the boat to a halt with the dive ladder at, or within easy reach of divers who might be at the buoy. If at all possible, the engine should be shut down at pick-up point arrival so that there is no possibility of prop injury to a diver in the water.

In the case of an emergency, getting the standby diver to the position of the divers on the surface, who should never surface off the float of the shot-line, will take longer than with small boat surface cover, even with a good boatman. However, an emergency should be dealt with by approaching the divers with the working boat.

All diving from a large boat should be done using a substantially weighted shot-line and a float large enough to support the divers and the float in even a strong current (6.2.7). The boat should remain in close vicinity to the buoy, keeping downstream of it. An up-current approach to the divers on the float at the end of the dive with the engine off allows the divers to be picked up safely. It must always be assumed by surface attendants that divers are cold and fatigued, and every effort should be made to recover them quickly.

It is usually an advantage to operate an inflatable or a small hard boat in conjunction with any dive support vessel over 10 m in length.

6.2.7. Ropework, terminology and use of ropes
(See also Sections 6.2.8; 6.2.9; 6.2.10; and 8.2.4).

Scientific diving depends both for safety and efficiency of work on the use of ropes and lines in many different ways. Some of these lines are fixed lines on the bottom, some are attached to buoys or floats and others are attached to the divers or between divers. Correct usage of ropes and lines can be an essential part of safe and efficient work. Incorrect use can result in delays, entanglement and be a contribution to serious accidents. In this section there is no attempt to describe the details of knots, correct rope materials, shackles, etc. which can be found in manuals of seamanship, or diving manuals. The intention is rather to show how each roping system can be used most effectively to maximize safety and accurate work.

Photo 4: Proper identification and use of a variety of ropes and lines are important components of successful scientific diving. *Photo: G. Stanton.*

Figure 6-1 shows the general deployment of ropes and lines for divers working on or near the bottom and Figure 6-2 shows the general deployment of ropes and lines for divers working entirely within the water column from the surface. The terminology comes from the traditional vocabulary of fishermen and sailors and cannot really be regarded as standard. Nevertheless, it is extremely important that a rope technique referred to in the text is correctly understood. For this reason alternative names have been shown based on different usage from several countries using English as a first language.

6.2.8. Buddy-lines
Buddy-lines are short lines of about a meter or two in length with snap-clips on both ends which are used for safely fixing one diver to another. Longer lines connecting divers underwater may be used in conditions of bad visibility, but if there are any currents or obstructions which may foul the longer buddy-line, their use is not recommended. If low visibility buddy-lines are used, an agreed communication system using rope pulls must be agreed on and practiced prior to beginning the dive.

Short buddy-lines can be carried by the scientific divers but if both are working on the shot- or sweep-lines (6.2.10), a buddy-line may get in the way and thus would create a hazard. A small float midway along the buddy-line can help to minimize the chance of snagging on the bottom.

A buddy-line is a tool that can be used to maximize safety in certain diving conditions and on certain jobs. Conversely, there are other conditions and jobs where a buddy-line would not increase safety and might cause problems. When deciding whether to use a buddy-line, or not, the Dive Supervisor/Person-in-Charge should consider at least these factors:

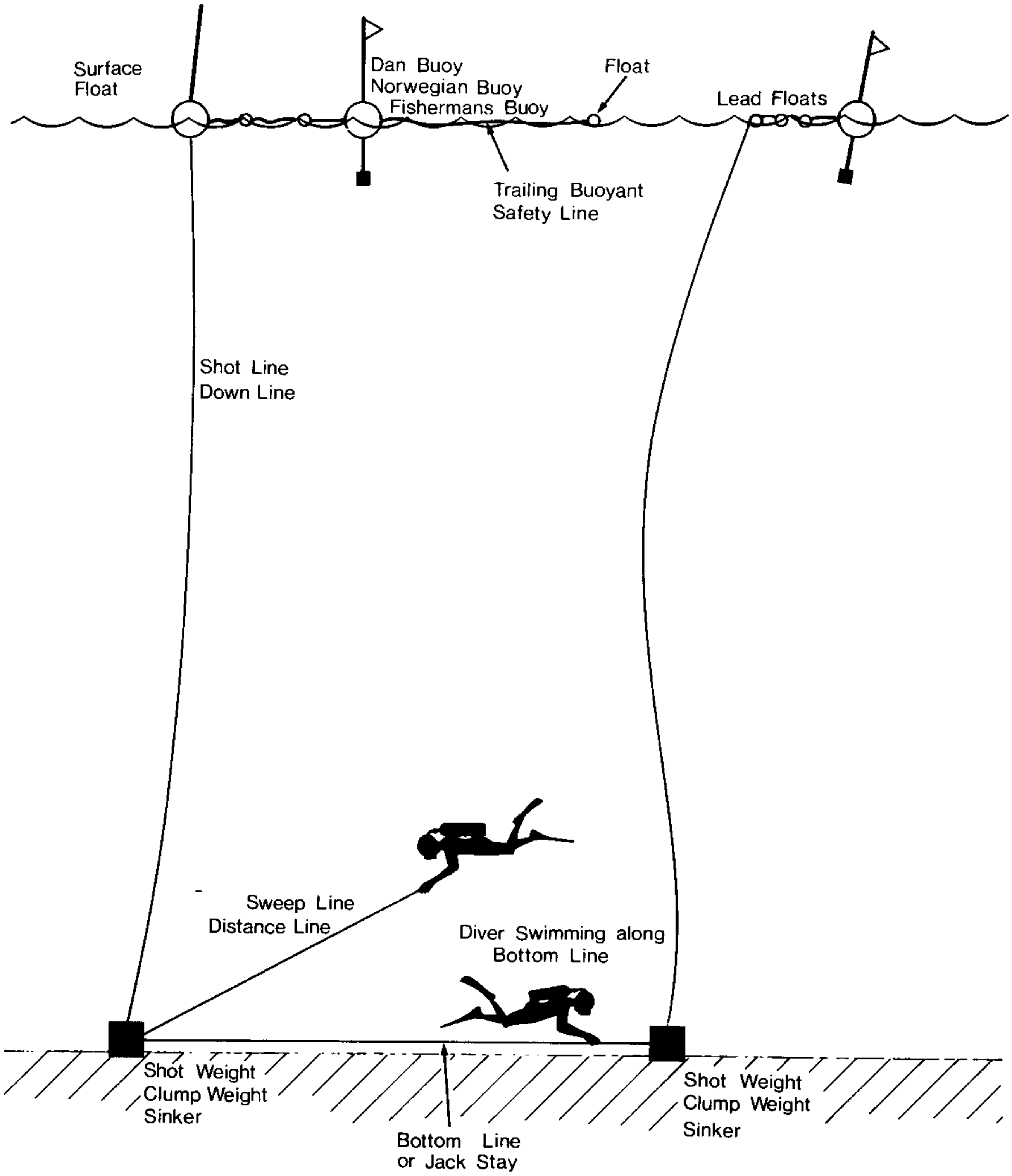


Figure 6-1. Divers working from ropes and lines that allow the divers to work on or up from the bottom.

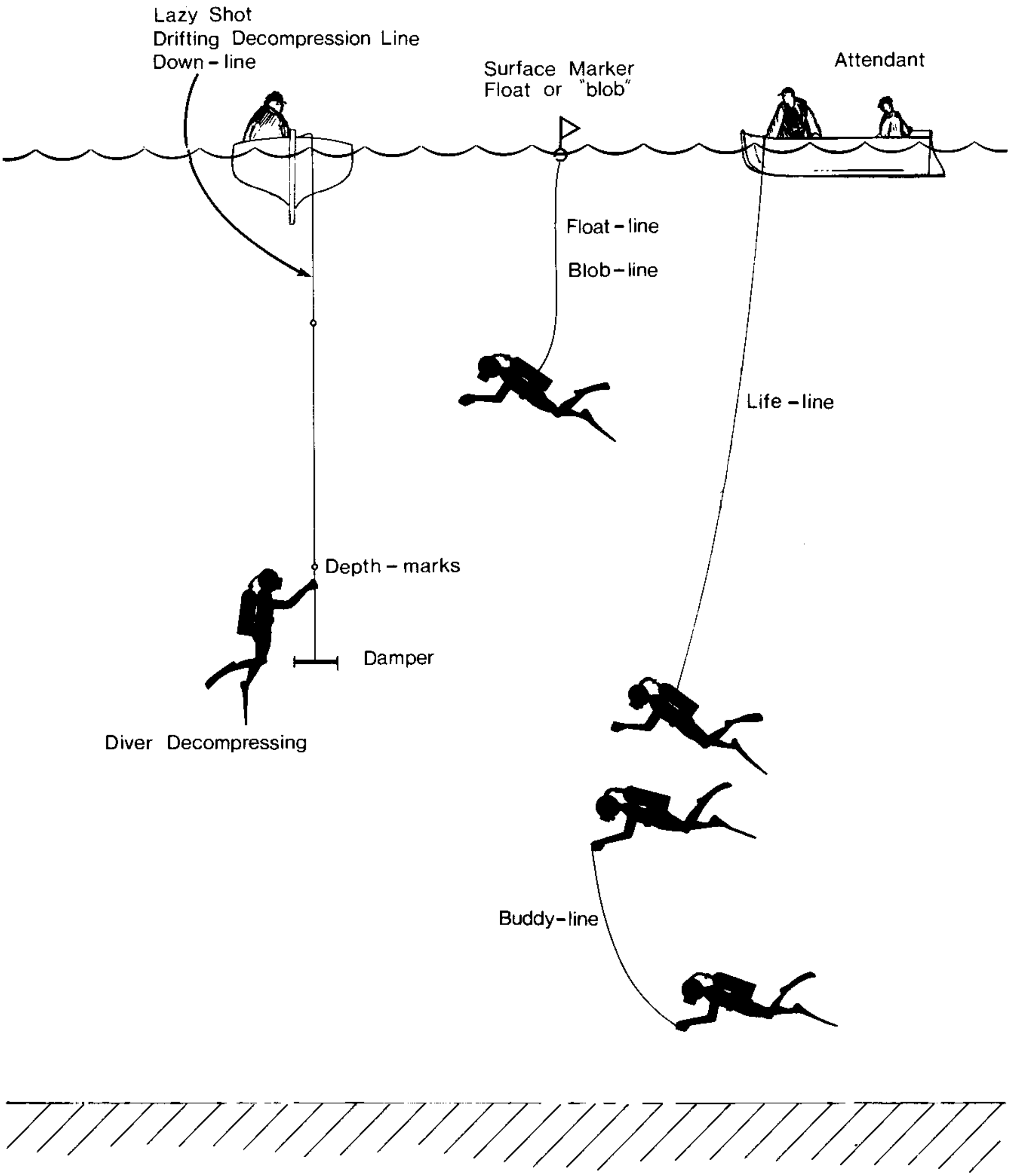


Figure 6-2. Divers working from ropes and lines that have no component of interaction with the bottom.

1. Are the divers likely to stay easily within visual range of each other throughout the dive?
2. Does the current or wave action tend to cause the divers to become separated beyond visual range?
3. Are both divers likely to be engaged in work that would prevent them from keeping visual contact?
4. Are the divers encumbered with equipment and ropes in such a way that a buddy-line might easily become entangled?
5. Are the divers working close to coral, wrecks, metal structures, kelp or other features or objects that would cause entanglement?

The Diving Supervisor is responsible for assessing the job conditions and deciding whether to use buddy-lines.

6.2.9. Life-line

This is a line that connects a diver directly to a surface attendant. In surface demand operations (7.3), together with the air line and telphone line, this allows a single diver to work safely underwater. It must be securely attached round the body of diver, or to the special strongpoint provided on some ABJL's, and must be strong enough to support more than the weight of the diver and all of his/her gear in air. In the event of an emergency, the diver can be retrieved, and there is also a line along which a standby diver can descend directly to the diver. Diving operations using life-lines in deep water are usually confined to diving near to the work-site in conditions of low current drag. In strong currents and shallow water a life-line is useful, provided that the work-site is always downstream of the attendant.

6.2.10. Shot- (buoy) and sweep-lines

Fixed-lines are usually needed in conditions where divers might get lost, disoriented, or separated from each other or from surface cover. In addition, fixed-lines can be an aid to accurate search and survey projects. These line systems are particularly useful in low visibility, coastal, tidal and estuarine waters.

Shot- and sweep-lines are the common working lines for shallow water scientific diving and allow the divers to remain in communication with the surface party while operating in a wide variety of current and surface conditions safely. It is recommended that sets of lines of 10 m and 20 m lengths with snap-clips on both ends of all lines be prepared as a standard part of the project gear. A set of lines for one team should consist of a minimum of 3-20 m and 5-10 m lines. The ropes should be woven and not too soft so as to have a tendency to go limp (nylon) and coil in the water or made from fibers that will fray and abrade a divers hands (blue polypropylene). Eight mm Terrylene is a good line for small boat operation. These lines can then be deployed as any of the line sets used by scientific divers in the course of their operation. The use of the sweep- and shot- lines are discussed in diving in fast currents (8.2.8), and they differ substantially from the ropes used in blue-water diving (8.2.4).

The shot-line (buoy-line, main-line, down-line) is the line between the surface buoy and a bottom weight or anchor and is deployed and recovered bythe boat; its strength and lengths depends on the type of operation (current strengths are important) and the nature of the boat deploying it. Large boats can winch up heavy lines and weights but small boat parties can only bring up lighter lines and weights. In spot diving the line is usually well weighted but in drift or traverse dives, there is usually only a 1 kg weight to keep the line under tension.

The sweep-line (divers'-line, horizontal-line) is a short line deployed and recovered by the divers underwater from near the base of the shot-line. It is usually 10 m in length as this allows the divers to range safely about the bottom on the shot-line and remain in rope communication with the surface. More than one coil of sweep-line can be carried underwater.

The trailing-line is 10 m or more in length and fixed to the top of the shot-line at or near the surface buoy. Its other end is supported by a small surface float. This line and buoy indicates current direction to the boatman, while at the same time providing a safety-line for divers who may come off the shot-line on ascent or at the surface.

6.2.11. Safety and equipment helmets

The use of safety helmets is recommended in certain situations:

1. When divers are working at or near the surface and cranes or derricks are in use from ship or shore.
2. When surface workers are using hand-held tools above a shallow diving site.
3. When divers are working on underwater or floating constructions or apparatus which could move or collapse.
4. When divers are approaching rocks on or below the surface in rough water.
5. When a helmet provides a good place to affix specialized equipment such as lights (8.2.19).

Safety helmets should be well vented so that the diver's head does not momentarily become very heavy with the weight of water upon breaking the surface; the helmets worn by canoeists are usually satisfactory for scientific diving (8.2.18; 8.2.19).

6.2.12. Communications

There are many forms of communication between divers and between divers and the surface:

1. **Direct visual.** In adequate visibility, hand signals, light signals or pre-arranged signalling such as written instructions and semaphore can provide good two-way communication. Standard lists of hand signals are published in diving manuals and logbooks.

2. **Voice.** Both telephone and wireless diver communication systems are available for in the water use and must be used in certain situations such as surface demand umbilical diving. Voice communication between divers, and diver to surface, depends critically upon the design of the voicebox, oral-nasal mask, helmet or full-face mask. The use of a mouthbox or full-face mask is essential for correct pronunciation of words underwater. Attention must be paid to equipment design and to breathing rhythm in order to prevent carbon dioxide accumulation. An air-filled 'underwater telephone booth' allows a number of divers to report to the surface by removing a conventional mouthpiece.

3. **Other acoustic.** Any pre-arranged signalling system such as revving the engine, banging on metal with a knife or small amounts of explosives can communicate or attract attention or convey a specific, pre-arranged instruction. Small explosives such as thunderflashes are fine in theory but are difficult to light in a small boat on a choppy sea in a rainstorm. They should not be used within 20 m of divers and for best sound transmission should explode just under the surface of the water.

4. **Rope or line.** Rope signalling plays an important part in underwater communications in conditions of poor visibility or during rope searches where divers are spread out more than they would otherwise be during a normal scientific dive. The number of pulls to convey instructions varies from diving association to diving association and from country to country; any scientific diving which involves the use of rope communications must use agreed on signals

and procedures. These are usually published in diving manuals.

5. **Writing.** Scientific divers usually carry a plastic pad for writing notes with a pencil. This pad can be used to write messages between divers.

Any means of communication between divers and surface results in increased flexibility of operation, economy of diving effort and much greater safety. Incidents may thus be prevented from developing into accidents.

All systems of communication should have a normal operation mode-surface listening and diver speaking, temporarily switched for transmission. When more than two persons are linked it is desirable to have a simple rule of procedure by which speakers identify themselves.

If using a telephone cable passing directly to the diver, it should be fitted with a light float to prevent underwater snagging of the slack cable. It should be noted that the manufacturer's information about telephone cable breaking strains frequently does not apply to the contained telephone conductor. Undue strain should therefore be prevented. The support boat should be large enough to permit proper cable handling by the surface operator when telephones are being used. Wireless ultrasonic communications sets are waterproofed and small enough to use from normal diving inflatables.

Diving flags appropriate to country and diving code should be displayed to communicate the presence of divers to those who are not in the diving group.

6.2.13. Recall signals

The meaning of all signals must be agreed on and understood. Any of the forms of acoustic or rope signaling (6.2.12) may be adequate. In an emergency, the ultimate recall is to pull up the shot-line along with the divers on it. Care must be taken not to pull the line in too quickly. This method should not be used if there is any risk that the divers are not attached to the shot, or if the diver's sweep-line could be fouled on wreckage, rocks or coral.

6.2.14. Homing gear

Directional acoustic navigation aids can be used for free-swimming along a predetermined course or for returning to any point. Where any of these systems is used, the dive should be planned so that the apparatus contributes to diving safety.

Surface communication by VHF radio is recommended for operations in which the diving site and the small boat cover are situated at distances more than about 0.5 km from the operational base or ship. This is particularly the case if the work involves changes of plan during a dive. Direct wireless communication from a diver via a cable to a surface buoy and aerial has been tried experimentally and might prove convenient in certain situations.

6.2.15. Buoyancy control

All divers shall wear a weight belt with a quick-release system accessible and capable of immediate release using either hand. Divers should ditch their weight belt before getting into a state of extreme fatigue. Institutions are encouraged to replace jettisoned weight belts at no cost to the diver.

Some cylinders in common use are so heavy that a diver wearing a twin set requires no weight belt. In this case the breathing set should be fitted with additional incompressible buoyancy so that a weight belt of about 4 kg is required.

An inflatable life jacket or stabilizer jacket of the refillable air type (ABLJ) is almost mandatory now for the majority of scientific diving situations. It should be capable of being filled from an integral air cylinder of sufficient capacity to provide an emergency air supply to a diver making an emergency ascent and should not be used except in emergency. A direct-feed from the main bottle is useful in some types of diving. An integral direct-feed and emergency demand regulator which allows air from the life jacket to be breathed combined with a good ABLJ gives the diver maximum flexibility and safety and is recommended for all scientific divers.

The use of an ABLJ to assist in the lifting of heavy objects is dangerous, especially if heavy objects are dropped by mistake. The diver must be able to vent air rapidly from the jacket in order to prevent an uncontrolled buoyant ascent. If heavy objects do have to be lifted it is recommended that a lifting bag be used except in conditions where this introduces an additional hazard or where it is impracticable, such as in strong currents.

6.2.16. Free ascents

The routine training of divers in the practical experience of free ascent techniques is controversial. Some fatal accidents have occurred in training, especially in submarine escape training towers.

It does not, however, seem reasonable to advise divers to rely in emergencies on physical skills and psycho-motor co-ordination for which they have no practice. The control of venting of the lungs in such a way as to maintain a buoyant ascent at a gentle rate with minimum swimming effort and without straining the lungs requires a control that is not instinctive. It is unsatisfactory that many safety authorities presently advise divers not to do training, but to use the method in emergencies. Book learning cannot provide the conditioning of reflexes and instill the necessary confidence and relaxation.

If divers are going to be advised to use free ascents in emergencies, they should be given practical training under closely controlled and supervised conditions, with medical advice.

Legislation, sports diving standards, regulations and naval practice vary from country to country on this issue. Those divers who have been fully trained in the method tend to rely upon it with full confidence. The Diving Control Board/Diving Officer should decide on the evidence available whether it is better to approve the training or forbid the use of the techniques altogether.

It is possible that the technique might be considered more acceptable in the disciplined circumstances of a well-controlled scientific diving program than in the sports diving environment. It is worth noting that divers will inevitably learn about free ascents from books and may be tempted to experiment on their own if not properly taught.

6.2.17. Perceptual deprivation underwater

The undersea environment produces various psychological changes in the diver which are not necessarily attributable to narcosis. Diving presents a natural form of sensory and perceptual deprivation. Some of the effects of such deprivation, which have been demonstrated experimentally, can be observed in the diver. These effects are even more pronounced when diving in turbid or mid-water.

Time duration is often underestimated, sometimes to quite a large degree, e.g. 50% or more. This should be borne in mind when diving with a limited gas supply.

Reasoning ability is impaired. This includes a wide variety of reasoning, such as mental arithmetic, logical comprehension and non-verbal reasoning. There appears to be a trade-off here between accuracy and time but this is not yet quantified. Errors are often made if one tries to solve the problem underwater in the same time it takes to do on the surface; whereas it often takes up to 60% longer to solve the same problem underwater, with usually a slight drop in accuracy. Where possible, all 'thinking' tasks should be completed on the surface before diving. Also, data should be collected underwater in its raw form and analyzed on the surface. Decompression tables should not be worked out underwater, except in emergency.

Memory, both short and long-term, does not function well underwater. Godden and Baddeley (1975) have shown, however, that items memorized underwater are better recalled there than topside.

In dives of a technical nature, e.g. surveys, thought should be given to debriefing the diver toward the end of the dive, while still underwater, or using umbilical systems with telephones to report data throughout the dive. This can be accomplished by giving the diver a formatted response sheet to complete for each job. Failing this, a response sheet may be given immediately on surfacing or while the diver is in a chamber. Such a sheet should take no more than 1-2 minutes to complete. A more efficient method is for the diver to give a verbal report to the supervisor over a diver communication system. If possible, this report should be recorded.

Where divers work in sequence on a task, it is advisable that they be debriefed immediately at the end of a dive, and that their observations be recorded in a standard format. This enables a consistent picture to be built up, in spite of memory problems.

Judgement/estimation of measurements is often unreliable, especially in turbid waters. Whether divers tend to under- or overestimate has long been cause for debate. Experimentally, both types of error have been reported (e.g. Luria, et al., 1967; Ono and O'Reilly, 1971). However, more recent research (Leach, 1982) has shown that the more turbid the water, the greater the tendency to underestimate measurements if the task is within the manual workspace. If the task is outside of the reach of the manual workspace, the tendency is to overestimate; there is a crossover distance at around 1.2 m from the diver. In over 90% of cases, measurements are reported from within 1.2 m. If measurements are to be made on a dive, then research tools should be brought underwater such as measuring tapes or scales printed on knives or other implements. As a last resort, all divers should know some of their own physical measurements, e.g. length of forefinger and forearm, span of hand, width of wrist, etc.

6.2.18. Narcosis and decision-making

Inert gas narcosis impairs many aspects of a diver's performance, both intellectual and manual skills. These narcotic effects, which have been likened to drunkenness, are normally felt at depths greater than 30 meters and increase progressively with depth. Stress and anxiety greatly exaggerate the effects of narcosis and can impair performance even with the use of a non-narcotic gas (helium). Frequently (daily) repeated dives tend to reduce these effects and increase the work capacity of the divers.

At depths greater than 50 m, practice dives should be increased gradually to a depth slightly greater than the projected working depth and should involve no work task. Only two divers should be involved. Only when divers are confident at depth should work be undertaken.

Surface/diver communication is strongly recommended, although care is necessary to avoid over-exertion and breathlessness from too much talking. Even if in communication, agreed on dive plans should not be altered in mid-dive by decision of the divers who may be narcotized below 30 m.

6.2.19. Decompression meters and dive computers

Decompression meters of the 1960s and 1970s were analogue instruments that attempted to model the behaviour of the human body as it absorbed and released gas during an exposure to pressure and return to the surface. Simple tests showed that this approach could not model dives effectively, and was particularly unreliable in repeat dives.

Since 1980 a number of much more sophisticated instruments, referred to as dive computers, have been developed that model the tissues of the body with up to 12 different half-times from 5 minutes to many hours and use physical or thermodynamic equations, which are re-computed digitally at frequent intervals. These instruments have proved more effective, and apparently safer. Since they give the diver many advantages, the urge to use them is very strong. However, some serious problems must be borne in mind. If we consider the apparent advantages first, the problems become clearer.

Apparent advantages:

1. The diver can perform a variable profile dive, not a rectangular profile dive, and the computer calculates only the gas that has actually been absorbed. Compared with the tables, which are based on a rectangular profile, there should be less gas in the body, and therefore the decompression required takes less time.

2. Decompression stops do not have to be carried out at any particular depth. As the diver ascends, the computer calculates the rate of gas loss from each tissue and indicates how much further the diver can ascend safely. The diver chooses the rate and depth of out-gassing to suit the work and weather conditions.

3. After surfacing, the dive computer shows how many minutes could be carried out, without need for decompression, at various depths on subsequent dives. The diver is therefore informed that it is worth re-entering the water to perform a short task, when, without the dive computer, he/she might have waited several hours. Taken to its logical limit, divers use this information to carry out five or more short working dives in a day, where some repeat tables would have limited work to two dives, and others would have required extremely complex calculations of uncertain reliability after the second dive.

These advantages are sufficiently important in terms of work achieved per day, and reduced costs and duration of projects, that they need to be very carefully examined. The key factor is that all the computers assume that solution and degassing are controlled by smooth analytic equations that are determined by the external factors of time and pressure only. In contrast, many physicians consider that there are some random and non-linear elements that initiate bubble nucleation and blood platelet accumulation. As soon as the diver ascends slightly and reduces the pressure, at any time during a variable profile dive, there is the chance that a bubble will start to nucleate. From that point on the critical equations, which determine whether the bubble will grow and cause a bend, are not those that are programmed into the computer. The designers of dive computers reduce this risk by recommending very slow rates of ascent at all times, so-called 'bubble-free' ascent. Again the evidence for the possibility of totally bubble-free ascent is controversial.

The viability and reliability of dive computers will only be confirmed ultimately by the endorsement of physicians and experts in diving physiology. At the moment this endorsement is not forthcoming, although several thousand such instruments have been sold, and many divers use them without apparent adverse effects. However, until truly objective tests on thousands of dives and divers have been carried out and published, Diving Officers should treat these instruments with caution.

The displays provided by dive computers vary. Different instruments provide different data on ascent time, duration to no-stop limit, surface interval time, permitted duration of next dive, etc. In all cases a partial ascent will result in the instrument computing the gradual degassing of the body, especially the faster tissues, regardless of whether the diver ascends to a specific depth and makes deliberate decompression 'stops'. Divers who use these instruments regularly tend to ascend slowly and steadily, often working during the ascent, and losing most of their gas at intermediate depths, rather than performing shallow stops of long duration. It is not clear how the instruments compute the effects of ascending too fast or ascending above the permitted 'ceiling'.

It is advisable to remember that the use of a dive computer is likely to encourage divers to make many more dives during a day, and that the divers will then be working in a state that is not provided for by any published tables. Whereas a few repeat dives may be permitted by published tables, with a conservative safety margin, dive computers can take no account of work level or cold, or other adverse conditions. As it is often the case with diving practice, experienced divers tend to play safe and work slightly within the limits indicated by the dive computer.

It is a sad fact that out of the millions of dives that have been conducted on scuba, accurate dive profiles have hardly ever been recorded. The traditional practice of recording time of leaving surface, arriving at bottom, leaving bottom and arrival at stops, and arrival at surface, is not enough to prove that two dives are identical. Thus the data base on which the effectiveness of decompression tables might be tested is very poor.

There is a further disadvantage attached to the present dive computers in that the dive profiles and decompression stops are not known and not recorded in any fashion. Apart from the total duration of the dive and the maximum depth, the diver has no data to enter into his/her logbook. In the event of a pressure related accident the diver's exposure profile is not known, and similarly the profile and decompression stops for previous dives are unknown. From the point of view of verifying the safety of the computer formulae, maintaining safety in general, or checking the safety of the instruments themselves, this is a problem. It is strongly recommended that divers who use these instruments attempt to record their dive profiles, particularly the final ascent phase, as carefully as possible. It is also hoped that the manufacturers of such instruments will, in future, include a dive-profile play-back function, which would enable the diver to retrieve the critical depth-time data.

Divers in scientific diving teams, whether employed, visiting divers or volunteers, shall not use a dive computer unless the type of instrument and specific model has been approved for use by the Diving Control Board or the Chief Diver.

6.2.20. Electronic instrumentation

Electronic instrumentation is rapidly replacing older techniques in scientific data recording underwater as the equipment becomes more specific, cheaper and easier to use. Direct measurement of environmental parameters such as oxygen saturation, temperature, salinity, etc. are now available to divers, at least for probe operation from small boats. This greatly facilitates much scientific work, particularly environmental studies bearing on organic pollution.

Electronic instrumentation in depth gauges, watches, air contents, diving computers and decompression computers are currently becoming available. There is no doubt that further development is inevitable, and that electronic instrumentation will make an impact upon science diving similar to that which has been made on many other fields of scientific endeavour.

6.3. Post-dive safety

6.3.1. Diver location aids

The wearing of a fluorescent orange hood by divers if there is any chance of their surfacing at distance from the cover boat increases the chance of location.

Further diver location aids are flares, rockets, dye markers, whistles and radio and light beacons. These gadgets are neither foolproof nor entirely reliable, and all depend upon common sense for effective use. The following points are relevant:

1. If a diver surfaces away from the work-site well within the planned dive time, he/she may not be missed immediately, and there will be less search effort than if he/she is overdue.

2. Depending upon surface conditions that allow divers' bubbles to be tracked, the occupants of the cover boat may realize that one diver has become separated from the others and would probably know in which direction the diver disappeared. The lost diver may therefore be expected to surface in a predictable general area.

3. Owing to the diver's low position in the water, although at times he/she may be able to see the cover boat, the research vessel and/or the shore, it does not follow that persons at those positions will see the diver. Flares, rockets and dye packets should not be wasted, but used when there is a high probability of the searchers seeing them. For example, the lost diver should not let off a flare when a boat is heading away, but wait until it is heading in the diver's direction.

4. Searchers in a small boat are unlikely to hear a whistle with the engine running. If it is known that divers carry whistles, they should stop the engine at frequent intervals. If the diver can hear those quiet periods, this obviously is the time to use the whistle.

6.3.2. Diver recovery equipment

Equipment for the recovery of divers onto small boats are generally rope ladders and handholds on the small boats and rigid ladders on large boats. Large ships can have diving platforms or even interior wells into which small boats can motor directly from the sea or inclines similar to those common on whaling boats on which small boats can be 'beached'. A diver in trouble should be man-handled wherever possible and roped at other times so that circulation is not constricted. Davits or crane may be needed on large vessels. Excellent techniques for recovery of unconscious divers have been developed by Hendrick (1986).

6.3.3. Life-saving and artificial respiration

Standard methods of life-saving must be taught as part of the diving training requirements for all divers. These methods are laid out in various countries in manuals and pamphlets. Life-saving associations and diving clubs and federations usually give courses which can be used by the scientific divers.

For deep-diving operations, experienced divers should be trained by a qualified instructor in the techniques of deep-diving rescue and recovery as laid out by CMAS, diving clubs and federations of clubs.

All divers should familiarize themselves with the procedure for Expired Air Resuscitation (EAR) and other forms of resuscitation, including External Cardiac Massage (ECM). These are also described fully in various diving manuals and handbooks (Appendix 2). Practical instruction in these procedures may be obtained through local ambulance associations or from local safety groups. It is recommended that one or more members of the diving team at any project site should have received formal instruction in first-aid.The administration of oxygen by first-aiders has been questioned by some non-diving authorities. Oxygen is often considered to be a drug, and there are laws in some states that regulate the use of oxygen. Rescuers and divers should be aware of such laws, especially if they specifically forbid the use of oxygen in a first-aid situation.

Supplemental oxygen is a very valuable treatment in the first-aid management of air embolism and decompression sickness. Breathing oxygen will eliminate some nitrogen from the body by producing a nitrogen partial-pressure gradient between the problem bubble(s) and the surrounding tissues. The pressure gradient causes nitrogen in the bubble to dissolve in the bloodstream and be eliminated through the lungs. Any increase in oxygen being supplied to the injured area will also be physiologically beneficial, especially if brain tissue is involved (11).

First-aid courses should include training in administration of oxygen. Oxygen resuscitation equipment should be held at dive-sites and on dive boats, provided that there is a person present who has been trained in its use.

Administering oxygen to a conscious, spontaneously breathing individual is not difficult and is usually safe with the proper equipment. The concentration of inhaled oxygen should be as near 100% as possible in order to achieve maximum benefit. A demand-type oxygen breathing unit with a tight-fitting, double seal oral/nasal mask and an adequate oxygen flow rate is necessary to deliver the required concentration. Constant flow devices (inhalators) using nasal cannula, simple elongated face masks, partial rebreather masks, etc. will only deliver low, ineffective concentrations (25% to 60%) depending on the metered flow rate. In the event that only a constant flow device is available, deliver oxygen at a flow rate of 10 liters per minute.

If the victim is unconscious or not breathing spontaneously, oxygen administration becomes more complicated. In this situation, the first-aider must have a thorough understanding of airway management and the use of associative equipment. Such techniques and equipment are beyond the scope of this Code. The diver and dive leader can only be encouraged to acquire additional special training. Many community colleges and scientific institutions offer Emergency Medical Technician (EMT) courses that include this type of training. Use of oxygen in the early stages of managing a diving accident victim may reduce of totally relieve the symptoms within a short time. If this does happen, do not be deceived into thinking that the problem has been completely resolved. Oxygen breathing must be continued, the victim transported to the nearest medical facility and a diving physician consulted. Oxygen breathing at atmospheric pressure must not be considered as a substitute for hyperbaric treatment in cases of decompression sickness and air embolism.

The provision of an adequate first-aid kit is essential for all diving operations. The requirements of such a kit will differ with different diving operations. Medical advice should be sought in advance, when working in remote locations or unfamiliar environments. Oxygen resuscitation equipment should be carried and divers trained to use it.

6.3.4. Emergency situation procedures

General discussions on the statistics of, and causes of diving accidents can be found in Appendix 2. All members of the diving team should be well enough briefed so that they can take independent action.

In an emergency, when there is a threat of loss of life, serious physical harm or grave environmental damage, a scientific diver may, at his/her own discretion, violate these and any future regulations. Divers who do so must notify the Diving Officer as quickly as possible. A written report of such instances shall be submitted to the Diving Control Board, explaining the circumstances and justifications for the actions taken.

6.3.4.1. Emergency diving equipment on research vessels

Oceanographic research vessels frequently have trained divers on board or scientists who are trained to dive, even when the cruise project in hand does not require diving. On all oceanographic operations there is the risk that cables or equipment may foul the ship's propeller, or that expensive equipment may become tangled underwater. On such occasions it is useful to have diving equipment available that can be used in emergencies.

Diving equipment, which has been put on board a research vessel for use in emergencies, is under the direct control of the Captain. The Diving Officer shall provide a set of regulations stating under what conditions the equipment can be used, and what qualifications of divers must be on board before the equipment can be released. If the equipment has to be used, a report must be submitted to the Diving Officer, written jointly by the Captain and the senior diver involved in the operation.

6.3.4.2. Action during an emergency situation

If the emergency arises underwater, the buddy-diver must render assistance. All divers should be trained in buddy breathing and should practice the technique underwater. The buddy-diver should assist the diver to the surface, on the surface, to the boat and afterward as instructed by the senior diver present. Then:

1.Proceed with assistance to the injured person, e.g. first-aid, artificial respiration, warming up, etc.
2. Recall all divers or swimmers to the boat or shore. If decompression would normally be required, balance the risk of abbreviated decompression, and the possible requirement for recompression later, against the immediate risks.
3. Contact doctor, coastguard, helicopter (6.3.5), home base, passing vessel or the nearest compression chamber as appropriate, using radio if possible.
4. Make sure that other members of the diving team are not at risk and that, in the haste of the emergency, no equipment has been left.
5. Proceed as fast as possible to the nearest port, hospital or compression chamber as dictated by the circumstances and the casualty's condition.

Note down immediately the details of the casualty's dive during which he/she was injured. Conditions of emergency often lead to neglect of completing the diving log, and make it impossible afterwards to work out how long the diver was in the water, or how much decompression the diver should have had. While this record may contribute only slightly to successful treatment of the injured person at the time, in the long term it is essential to the understanding of diving accidents and their avoidance. Isolate and keep under lock and key every item of the injured diver's equipment for later analysis.

Particularly if recompression is required, try to ensure that all recent dive record sheets or logbooks are available for the doctors, as this may assist treatment. The details of the diver's last medical examination may also be useful if it can be obtained quickly.

If the accident is fatal, or seems likely to result in a fatality, notify the Director of your establishment or Head of University Department as soon as possible. This person will notify the next-of-kin. In the event of a fatality, the doctor involved, or your Director, will notify the statutory legal authorities.

When the immediate emergency is passed, and all necessary steps have been taken to assist the casualty, a full record of the incident should be compiled. Depending on the exact sequence of events, the Dive Marshal/Dive Master may have time, e.g. while the boat is heading for shore, to start making notes, obtaining details from other divers, noting exact times, etc.

Remember that the buddy of a diver who develops symptoms of decompression sickness, even on a dive apparently carried out according to the tables, may also develop symptoms later and require recompression.

6.3.4.3. Reporting procedures

The amount of detail required in, and the circulation of, the report depends on the seriousness of the incident. The procedures given here are the minimum which should be carried out in the various circumstances.

Accidents resulting in no permanent injury. Such accidents include large flesh wounds, broken bones, concussion, decompression sickness and other injuries which would prohibit the diver from normal work or diving for a period. The accident should be reported in full to the Diving Officer, who will decide whether there is any evidence of negligence or unsafe diving practice. Before recommencing diving, the injured diver should have a full medical examination.

Accidents resulting in permanent injury or inability to dive. The fullest possible report should be compiled by the Dive Marshal/Dive Supervisor/Person-in-Charge and submitted to the Diving Officer. This should be submitted, with the Diving Officer's comments and recommendations, to the Director of the establishment or Head of Department, or Diving Control Board.

Periodic medical examinations of the injured diver should be made to establish progress and rate of recovery. A diving physiology research laboratory or other experts concerned with diving medicine should be consulted.

Depending on the seriousness of the disability and the circumstances of the accident, the injured person may have a claim for damages against the employer, or the organizers of the dive. To establish this claim and the liability or otherwise of the employer or dive organizer, a full enquiry with legal advice may have to be carried out.

Accidents resulting in fatality. The Director of the establishment, Diving Control Board or Head of Department must be informed at once. The normal civil legal enquiry into cause of death will be conducted as a matter of course, but it is almost certain that there will be a fuller enquiry afterwards to establish the circumstances of the accident in the interests of improving diving safety, or the settlement of claims for damages, etc. The fullest possible report must be compiled. Expert medical opinion must be obtained.

Specimen accident report forms are given in Appendix 6.

General instructions for dealing with accidents are:

1.Keep calm and reassure patient.
2.Keep patient on oxygen and incline head downward, left side down during transportation.
3.Ensure paramedic/physician understands about the effects of gas and cardio-vascular interaction if they have not dealt with decompression sickness.
4.Do not stop giving oxygen to a diving accident patient even if patient is breathing normally unless there is a need to reopen the airway, or the patient shows signs of oxygen convulsions (without pure oxygen, bubbles will combine with nitrogen and aggravate symptoms).
5.Keep patient out of hot sun, watch for shock and protect patient from environmental factors.
6.Do not give pain-killing drugs.
7.A complete history of all events leading up to the accident and evacuation must be forwarded with the patient.
8.Depth gauges, tanks, regulators and other diving equipment should be forwarded with the patient and should be properly tagged, or at least set aside without tampering, especially if the accident was fatal.
9.Be aware that a well-trained diver may be the most knowledgeable person on the scene regarding diving accidents and must, therefore, make a continuing effort to ensure that proper treatment is given.

6.3.5. Evacuation by helicopter or other aircraft

Each evacuation by helicopter presents unique problems. Knowing what to expect and the procedures to follow will save time, effort and perhaps a life, as well as not further endangering the victim or the crew of the helicopter. Aircraft evacuation is subject to the same general instructions, especially with regard to maximum recommended altitudes.

1.Request a helicopter with a medic crew and oxygen.
2.Try to establish communications with the helicopter. If your radio does not have the necessary frequency try to find another radio. Mark position of the victim by use of smoke flare on sighting the helicopter as there may be other boats and divers in the vicinity.
3. If pick-up is from a boat, maintain a speed of 10 to 15 knots into wind about 20 degrees on port bow. Put all antennas down, if possible without losing communications. Secure all loose objects on or around the decks because of the strong downdraft generated by the helicopter. Always let the lifting device or cable touch the boat before handling it to prevent electric shock. Do not secure the line trailing from the helicopter, basket or any cable from the aircraft to the boat.
4. Make sure the patient is ready in advance of the transfer; time is critical both to the victim and the hovering aircraft.
5. Signal the helicopter pilot when all is ready, using hand signals by day and flashlights at night.
6. Place life jacket on patient.
7. Tie patient in basket, face up.
8. Attach personal information such as name, address, age, what happened, and what

medication has been administered, if any.
9. Ensure that flight crews know that it is imperative to fly or pressurize aircraft below 220 m to prevent intensification of decompression sickness. Oxygen administration to victim should continue.
10. Provided aircraft can handle the extra weight, the diving buddy should also be transported with the patient, because he/she also may require recompression and can provide information, comfort and contact with the patient's relatives and friends.

6.3.6. Radio procedures

In different countries there are different official attitudes toward the possession of transceiver radios. In North America and Australia, for instance, radios are freely available to citizens and are widely used; some other countries also practice relatively free use. Other countries such as Ireland require licences and in some cases a written or practical examination in radio procedures and use. But even in countries which officially require a licence, enforcement varies and official policy changes from time to time. In other countries possession of radio equipment by a citizen is severely restricted and may even be held to be a criminal act.

Radio procedures vary in practice from country to country but generally some broad principles apply:

1. Know at what times emergency channels are being monitored and the frequencies of these channels. If possible know where the monitoring stations are and what the range of your radio equipment is.
2. Stay on the air broadcasting for the shortest possible time, this conserves your batteries (broadcasting uses more energy than receiving) and gives others time to talk to you. Also other people may wish to use the frequency for a message of even greater urgency.
3. Use a call sign. Identify yourself first at the beginning of each transmission statement. Include your position in this statement in even a general context.
4. Do not panic and signify a greater urgency over the radio than the situation justifies; there are three international call signs signifying different levels of urgency that will allow those coming to your aid to implement an appropriate response. These are paraphrased from international radio procedure instructions and should be repeated in groups of three:

a. **PAN-PAN-PAN.** Stay on this frequency. I will have a message that concerns safety but there is no immediate urgency.

b. **SECURITÉ-SECURITÉ-SECURITÉ.** Stay on this frequency and keep the channel clear. I have a message that involves safety and there is some urgency.

c. **MAYDAY-MAYDAY-MAYDAY.** This is an all-purpose distress call for immediate aid. Persons and craft or vessels are in imminent danger. Emergency is of a life-threatening nature. With lights or other signaling, **SOS-SOS-SOS** conveys the same message.

Practice radio procedures using available manuals for pilots or the literature that is often supplied with the radio. Practice especially the saying of numbers and the Alfa, Bravo, Charlie, etc. phonetic alphabet, which is used locally. These vary from language to language. The international language for air traffic control and for pilots is English and most radio traffic is conducted in English.

SECTION 7. DIVING SYSTEMS OTHER THAN SELF-CONTAINED AIR

7.1. Introduction

For reasons of prolonged endurance, compactness, absence of bubbles and/or noise, it is sometimes necessary to use diving equipment other than scuba containing compressed air. Because of cost and complexity, these methods have not been widely used in the past. These alternate gas mixtures and supply systems are now increasingly being used by underwater scientists, particularly in saturation and habitat diving.

The use of non-scuba equipment usually requires specialized training not available to scientific divers except through commercial or Navy schools. In different countries there are various Navy manuals and codes of practice which cover the use of the equipment.

7.2. Scuba, mixed-gas, surface demand and other systems

This section summarizes very briefly the characteristics of the various non-scuba systems using different gas breathing mixtures. The technical requirements as regards training, safety precautions, etc. for each type of equipment are listed in later sections, as shown in brackets:

1. **Surface demand, air** (7.3). Very long endurance, relatively cheap, limited horizontal range, excellent communications, low breathing resistance.

2. **Surface demand, mixed-gas** (7.3). Very long endurance, limited horizontal range, excellent communications, low breathing resistance, reduced decompression times.

3. **Underwater habitats** (7.4). Endurance of days or weeks, excursion dives without decompression, advantages of saturation, very expensive, requires substantial permanent surface support teams.

4. **Lock-out submersibles** (7.5). Long horizontal range, depth range to about 100 m or more, advantages of umbilical diving with communications, option of different gas mixtures, very expensive, requiring support ship and technical back-up.

5. **Oxygen closed-circuit** (7.6). Small light sets, low acoustic noise, very low breathing resistance, long endurance, absolute depth limit of 8 m.

6. **Oxy-helium bell diving** (7.7). Depth range greater than 100 m, in-water duration of hours, voice communications, limited horizontal range, very expensive, requires extensive support ship or platform, and massive technical back-up.

7. **Mixed-gas scuba** (7.8). Prolonged endurance, reduced decompression, reduced maximum depth, good horizontal range, moderately expensive, specialist training of personnel needed.

Only a few scientific establishments have experimented with these systems outside the Navy and commercial sectors. Dr. Alan W. Hulbert, Center Director or David A. Dinsmore Operations Director, Undersea Research Center, (NOAA) NUR, University of North Carolina at Wilmington, 7205 Wrightsville Ave., Wilmington, South Carolina 28403, USA, would be good contacts for any group planning to develop diving based on these specialized breathing systems.

A problem with all mixed-gas systems is that cylinders may be filled, but not properly labelled or documented, and a subsequent user may not know what gas mixture is in the cylinder. Extreme discipline and control is needed in this respect. A diver could be seriously injured or killed by diving with the wrong mixture and making the wrong assumptions about maximum depth or bottom time. The safest rule to apply is that if any diving cylinder is found to be unlabelled, and the gas mixture and date of filling is not recorded, then the cylinder should be emptied.

When scientific diving is being conducted with self-contained equipment other than open-circuit scuba on compressed air, work-up dives should be conducted as recommended in Table 4.1. The time lapse from the last working dive should be calculated from the last dive carried out using the same type of equipment.

When a working scientist is using self-contained equipment other than open-circuit compressed air scuba, it may be convenient to have the standby diver or buddy-diver on compressed air scuba. However, there must always be at least one other trained diver on the surface who has experience with the specialized equipment that is in use.

7.3. Surface demand air and mixed-gas

Surface supply diving applies to diving operations where divers are supplied with breathing gases by an umbilical from the surface.

A surface supply demand regulator should be supplied by an air or gas bank on the surface which has adequate reserve for the work in hand including decompression, or from a compressor via a gas storage unit having adequate reserve to bring the diver to the surface with time for decompression in event of failure of the compressor. Compressors shall be operated by a competent attendant who, if circumstances permit, may also be the diver's tender. The attendant is responsible for operating the breathing mixture supply system. The surface attendant on the gas hose should be a diver fully trained and experienced with the surface demand equipment. Each diver in the water shall be tended by a separate diver's tender.

Photo 5: Surface demand air systems may be ideal for some scientific diving projects. *Photo: G. Stanton*

The diver should be equipped with a reserve cylinder which can be turned on easily, or which automatically turns on, in the event of interruption of the surface supply. The reserve should preferably be adequate for surfacing including decompression. Where surface supplied equipment has not been designed to be used with a bail-out system, the diver shall wear an open-circuit scuba apparatus complete with an available regulator.

Each air line supplying air to a diver should be fitted with a pressure gauge downstream of the supply valve and installed so that the surface attendant can read it easily. The lower end of the hose should be attached to the diver's harness so that drag on the hose is not transmitted directly to the demand valve or mouthpiece. There must be a non-return valve at or near the demand regulator so that gas from the reserve cylinder does not vent in the case of failure of the hose, and low pressure in the hose cannot be transmitted to the diver.

A standby diver also with surface supply should be ready to enter the water. The standby system should also have voice communication and a longer umbilical than the working set. Two divers in the water can act as standby for each other.

In conditions of strong current a life-line should be used. It may be inadvisable to use surface demand equipment when working among mooring ropes or other lines to the surface or in kelp beds and in high currents.

Whenever possible an integrated communication system should be used, or a telephone wire should be run in conjunction with the hose or life-line; one of the main advantages of a tied diver is that clear, telephone communication with the surface is possible (Bevan, 1985; Walker, 1986, pp. 258).

7.4. Underwater habitats

Underwater habitats are artificial environments placed on the seabed or held at a fixed depth which are pressurized usually to near the ambient pressure of their depth. They contain living and working space and allow divers to remain underwater for extended periods of time. They allow diving excursions to be made longer than permitted by the standard air decompression tables that are designed for divers descending from, and returning to the water surface.

Photo 6: Although extremely expensive, underwater habitats are ideal for research that requires scientists to spend days or even weeks beneath the surface. *Photo: G. Stanton*

7.4.1. Introduction

Current underwater habitats are being designed to meet the requirements of a broad range of diving scientists. By incorporating saturation diving techniques with these work platforms, researchers have the capability of living and working for extended periods of time within the environment they are studying. This allows for the design of observation schemes and experiments which are otherwise not feasible when diving from the surface (Hydrolab Manual, 1984; Miller and Koblick, 1984).

7.4.2. Saturation diving

The term 'saturation' as used in diving refers to the body's tissues and their capacity for absorbing inert gas at a given depth. When the tissues have absorbed all they can at a given depth, they are said to be saturated, and the amount of decompression necessary to rid the body of this inert gas will not increase with continued time at that saturation depth.

7.4.3. Safety considerations on saturation

The primary safety consideration for saturated divers is that the habitat rather than the surface is their refuge in the event of a diving emergency.

7.4.4. General procedures

While each habitat program has specific procedures unique to that system and program, divers in saturation must always:

1. Recognize that they are dependent upon the surface personnel for support.
2. Familiarize themselves with the saturation system, its operation and emergency procedures.
3. Be knowledgeable about fire safety.
4. Understand the diving equipment and its proper use.
5. Be familiar with the study area and any navigational aids available.
6. Understand procedures and limits for excursions from saturation depth.
7. Plan missions and excursions that are compatible with safety guidelines, equipment, depth, excursion limits and the abilities of the divers involved.
8. Assume responsibility for their own safety as well as their buddy's.

7.4.5. Emergency procedures

Complete emergency procedures are developed for each habitat system and must be understood by surface personnel as well as saturated divers. Potential emergency situations may include the following:

1. Fire.
2. Loss of power.
3. Loss of communications.
4. Habitat flooding.
5. Habitat atmosphere becoming contaminated.
6. Accidental surfacing of a saturated diver.
7. Diver out of air.
8. Injured diver.
9. Lost diver.
10. Decompression sickness after excursion.
11. Loss of primary breathing gas source to habitat.

7.4.6. Health care

Throughout the history of habitat programs, the most common health problems have included ear infections, skin rashes, inflamed sores and diarrhoea. By following a strict regime of completely drying one's ears after every dive, washing thoroughly daily with soap and water and periodically washing out wet suits, these maladies can be reduced or eliminated. In addition to the above, heat loss is of concern to the saturated diver. By wearing properly fitting thermal protection outside the habitat and warm dry clothing inside, heat loss can be minimized. Full medical precautions are most effectively described in proprietary commercial saturation diving manuals.

7.4.7. Hazardous materials

To reduce the possibility of fire, atmospheric contamination or health problems to the inhabitants, certain groups of materials must be excluded from the hyperbaric atmosphere of the habitat:

1. Flammables.
2. Volatile materials.
3. Volatile poisons.
4. Mood-altering drugs.
5. Medications whose effect may be altered by pressure.
6. Heavy metals or their salts.

7.4.8. Excursion diving

A saturated diver must adhere strictly to vertical excursion limits outlined for a particular habitat diving program. There is a danger of developing decompression sickness both in the water by an ascent shallower than the habitat or on returning to the habitat after a descent deeper than the habitat.

7.4.9. Decompression after saturation (Also see Section 11)

Decompression procedures after a saturation dive vary with different systems. Factors determining the decompression procedures include:

1. Depth of saturation.
2. Gas mixture used.
3. Depth and duration of last excursion prior to decompression.
4. Time elapsed since last excursion.

Depending on the habitat system used, divers may be decompressed inside the habitat, either on the bottom or at the surface; brought to the surface in a pressure vessel, mated to a surface chamber and decompressed; or swim from the habitat to the surface and immediately enter a surface chamber and be recompressed to saturation depth and begin decompressing.

7.5. Lock-out submersible

A lock-out submersible is a vehicle that allows divers to be kept at variable pressures on the surface and on descent and ascent while allowing them to dive directly from it following 'lock-out' after reaching depth.

Some scientific uses for lock-out diving are for exacting, manipulative experiments, sampling micro-habitats not accessible to a manipulator and collecting fragile and delicate organisms. The lock-out submersible may be used for long excursions from undersea habitats, while maintaining the diver at constant pressure; also it may be used by the habitat diver for travel to and from greater depths, allowing for safe, dry decompression before returning to the habitat (Youngbluth, 1983; 1984).

7.5.1. Design principles and applications

The lock-out submersible has, in addition to the 1-atmosphere chamber, a separate chamber capable of pressurization which permits a diver to exit the submersible at depth (Busby 1976, 1981; Haux, 1982). Divers may be transported to the study site at surface pressure or at storage depth from saturation. The dive chamber is then pressurized to a slightly greater pressure than that of the ambient depth, thus allowing the dive hatch to be opened.

The benefits of lock-out diving include greater safety and comfort for the diver and immediate decompression following return to the submersible. Also the submersible pilot is usually able to control the gas supplies and decompression, thus avoiding misjudgements by the diver owing to the effects of narcosis. Some lock-out submersibles are capable of mating with a surface, double-lock, decompression chamber which allows food and medical supplies to be passed to the divers.

7.5.2. Operational procedures

Divers must complete training prior to lock-out for familiarization with dive gear to be used and with operating procedures for compression and decompression of the submersible's dive chamber. A shallow water lock-out dive should be made prior to deep or mixed-gas dives. Current velocity, direction and bottom obstacles must be assessed before diving. Precautions must be taken to prevent pinching of the gas supply hose in case the submersible shifts from current or surge during the dive.

Equipment: The following gear must be used:

1. Umbilical consisting of a non-kinking primary gas supply hose, and a communications wire linking diver, tender and pilot.
2. If scuba is necessary, then a neutrally or positively buoyant safety line must be tended by the dive tender.
3. Bail-out emergency bottle with either air or mixed-gas, depending on the composition of the primary supply gas.
4. Heavy-duty nylon web harness with lifting 'D' ring.
5. Firm attachment for umbilical to diver's harness.
6. Lifting device capable of recovery of unconscious diver into dive chamber shall be rigged and ready.
7. Weight belts must not have quick release buckles.
8. Flotation vests must never be worn, especially those vests with CO_2 emergency cartridges.

Pressurization: Air or nitrox is recommended for dives less than 50 m and helium-oxygen gas mixture for dives deeper than 50 m. The dive tender should control pressurization rate to allow immediate attention in the case of equalization difficulties.

Decompression: In planning total bottom time for a dive, adequate time must be allowed to return to the submersible, to retrieve the umbilical and to secure the dive hatch. The pilot or tender should control decompression. Oral-nasal masks must be available with oxygen supply.

7.6. Oxygen closed-circuit

Oxygen diving must only be carried out after personnel have received a full course of instruction from a Navy establishment or other establishment experienced with this mainly military equipment. Diving must be conducted in strict accordance with whatever rules apply to the particular equipment and usually full consultation must be made with the manufacturer to arrange for suitable training.

Normal rules concerning diving pairs and standby divers apply; it may be an advantage to have the standby diver equipped with scuba rather than oxygen equipment. No oxygen diving should take place unless at least one experienced diver fully trained in oxygen equipment remains on the surface during diving.

Gas must be medically pure oxygen and special care must be taken to ensure that all pipes, seals and taps are free of oil and grease.

Flow-rates must be checked at the start of the project, and weekly thereafter. Working diving on oxygen should not be carried out deeper than 8 m.

Divers who normally work with compressed air should, when preparing for work involving oxygen diving, carry out work-up dives according to a recognized schedule.

7.7. Oxy-helium and bell diving

Variable amounts of oxygen and helium are supplied to the diver as a breathing mixture in order to reduce narcosis, avoid oxygen poisoning, reduce gas density and shorten the time of inert gas flushing during decompression. Much of this diving is done from bells.

7.7.1. General principles

To increase capability of safely diving to depths greater than the limit for air diving operations (8.2.21) and avoid nitrogen narcosis, oxygen-helium diving techniques must be used.

Two basic categories of diving can be identified:

1. Intervention diving for short exposure to a maximum depth of about 100 m.

Intervention diving can be carried out by experienced scientific teams without an extensive logistical and equipment support. Surface supplied diving techniques are recommended, while free diving using closed, semi-closed or open-circuits, and particularly scuba diving with bottles-filled with oxy-helium mixtures, is discouraged and is considered excessively dangerous. Decompression sickness caused by helium gas is more likely than air to attack the nervous system and cause permanent disability. With an umbilical hose and safety-line the diver is always tethered and safety is improved by a virtually unlimited gas supply, along with a secure voice communication system. Umbilical facilities may be changed to oxygen or nitrox supply for decompression on ascent.

2. Saturation diving for greater depths and/or extended bottom time missions.

Saturation diving requires a pressurized bell and a complete diving system; civil research establishments rarely can manage these high cost and bulky equipment sets and so, usually, saturation bell diving is carried out in conjunction with commercial companies or with the Navy (Trent and Orzech, 1984; Keith and Frey, 1979; Colantoni, 1983).

7.7.2. Guidance for operations

Oxy-helium diving is technically and physiologically more complex than normal scuba diving, and any diver approaching oxy-helium must first be fully qualified and trained in air diving operations. If semi-closed equipment is to be used, special training is required.

1. Fullest discussion with the Naval, commercial, or government authorities must be held before considering this method of work; personnel and equipment must be selected carefully.
2. All personnel shall attend a suitable course on the equipment to be used, including training in a decompression chamber on the mixtures to be used and pool and sea practice dives.
3. Decompression must include stages breathing oxygen, nitrox or air.
4. Only approved decompression tables must be used for the dives (Appendix 3).
5. Diving must never be carried out without an on-site compression chamber with a transfer-under-pressure facilities. It must be operated by a fully-trained operator.
6. Divers should be equipped with a full-face mask or helmet. An emergency cylinder and

suitable thermal protection should be worn.
7. A tender on the surface should handle the umbilical and may maintain the communications, while a fully equipped standby diver must be prepared to enter the water immediately for emergency assistance. These attendants should always be divers trained on oxy-helium equipment.
8. A suitably qualified person shall control and time all the procedures and maintain a complete diving log. He/she should be responsible for the possible use of the decompression chamber.
9. An open bell or stage for recovery of divers during in-water decompression stops is also recommended as well as a heating system, i.e. warm water circulation, to compensate for loss of body heat owing to the longer than usual times spent in the water and the thermal transfer properties of helium in the breathing mixture.

7.7.3. Legislative requirements

Oxy-helium diving is controlled by detailed offshore industrial legislation in most countries where it is practiced. Scientists wishing to use these techniques may have to comply with government regulations and conform to commercial practice.

7.8. Oxy-nitrogen/ self-contained mixed-gas and modified air

Conventional scuba equipment can be altered in performance by using oxygen-enhanced breathing mixtures, either 40% or 60% oxygen. Any equipment that is used to store or handle pure oxygen must be specially designed for the purpose, and the risk of combustion is such that lubricants and rubber or plastic components must not be employed unless designed for use with oxygen. Under no circumstances should ordinary open-circuit equipment be used with pure oxygen.

The use of an oxygen-rich breathing mixture provides greater endurance at a given depth before the diver will require decompression stops during ascent. The tables for calculating the 'equivalent air depth' can be found in Navy diving manuals. Since the partial pressure of nitrogen is reduced, the equivalent air depth is shallower than the real depth of the dive, and decompression is also reduced. On the other hand, the higher partial pressure of oxygen means that oxygen poisoning will occur at depths shallower than the maximum depths on pure air; this depth limit must also be calculated before the dive and never exceeded.

Although it seems simple to use an oxygen-rich mixture in open-circuit scuba, because the equipment is so simple, extreme discipline is needed to make sure that divers stay within the safe range of depth and make the correct calculations for ascents. The technique has been used successfully in some university and institute diving groups, but it is recommended strongly that divers planning to use such a system attend a full training course in oxy-nitrogen mixed-gas diving.

Oxy-nitrogen mixed-gas can also be used in semi-closed circuit or completely closed-circuit systems. The older types of sets, usually designed for military use, have a reducing valve that feeds pre-mixed gas at a constant rate into a flexible counter-lung. The diver breathes the gas from the counter-lung and exhales through a carbon-dioxide absorbent, with the scrubbed gas going back into the counter-lung. In this way the diver breathes each unit of gas several times and removes more oxygen from the gas than on an open-circuit system. Professional training is mandatory, either at a commercial or military diving center. The equipment requires careful maintenance, and extreme discipline is needed in filling sets, changing carbon-dioxide absorb-

An oxy-nitrogen mixed-gas breathing system gives prolonged endurance for a given weight and volume of equipment and has a reduced bubble outflow compared with open-circuit scuba. It is also quieter.

Since 1965 there have been a series of totally closed-circuit mixed-gas breathing systems. The principle is to use a sensor to measure the partial pressure of oxygen in the breathing circuit, with an electrical output that adjusts the flow of oxygen and inert gas from separate cylinders, so as to keep the breathing mixture within safe limits. The objective is to obtain a very quiet set, with no bubble noise, and very long duration in relation to weight and volume. Some models have been developed for military use, but a number have been marketed for commercial or scientific use (Hanlon et al., 1983). Reliability of the gas control system is obviously critical, and in order to obtain this reliability, sets have become complex, expensive and require very professional maintenance. The performance of military sets of this type is not available, but it is fair to say that no set, which is commercially available, has yet received wide use. Since this type of equipment is still uncommon, very careful training would be required, usually in conjunction with the manufacturer, or a training establishment recommended by the manufacturer.

7.9. Multiple mixture diving, tri-mix

Multiple mixture diving is currently regarded as being outside of the range of breathing mixture supply systems available to scientific divers for use in the course of their work.

7.10. Snorkel diving as part of a scuba program

All the time spent underwater by staff engaged in snorkel diving during the course of scuba operations should be taken into account for nitrogen deficit-table purposes. Even though the diver is not breathing compressed air, gas exchange with the divers tissue's is taking place while diving with a snorkel. It is known for decompression sickness to afflict deep diving snorkelers who spend considerable time at depth, and mixing snorkel and scuba demands consideration of all time spent under pressure. Snorkel diving that does not exceed 2 ATM following scuba may usefully extend the scientific work programme but the time of exiting the water after the last snorkel must be considered as the end of the overall diving schedule.

Snorkel divers must be visually observed at all times. Snorkelers should be strong swimmers and should show proficiency at the working depth prior to work diving. It should not be necessary to change weight belts for a diver to transition from scuba to snorkel. The wearing of an inflatable life-jacket or ABLJ during snorkel diving should be mandatory, even if easily dumped weights are worn.

SECTION 8. DIVING IN SPECIAL AND EXTREME CONDITIONS

8.1. Introduction

Scientific research diving by its nature must often be carried out in special and sometimes extreme conditions, e.g. fast currents, zero visibility, very cold water, etc. since the scientific requirement controls the location of the diving site. Special conditions can be either largely environmental and naturally occurring, or artificial and dependent on technical or industrial factors.

The recommendations in the following subsections are intended to be supplementary to other established diving codes and to other sections of this Code. In every subsection it is assumed that the divers have been adequately selected and trained on the appropriate equipment, briefed and trained on the conditions to be expected, etc. and that proper support boats, communications and back-up facilities will be provided. As far as possible, each subsection deals with the special problems which can arise in scientific diving and not with the many diving skills and practices that are applicable in most diving situations.

8.2. Environmental situations and extremes

Where a complex working situation arises, such as working in heavy surf, in a remote area, or carrying out deep dives at night, project organizers are recommended to correlate all the relevant sections of this Code and to prepare a set of orders or regulations for their project, which will usually be based on this Code and normal diving practice. It is important to have accurate knowledge of the conditions which the personnel are likely to encounter, so that adequate safety precautions can be organized in advance.

If two or more conditions referred to here in separate subsections are combined, then the combination of the recommendations in each subsection may fall short of providing adequate safety, since danger factors tend to multiply. In some cases the combination of circumstances may require the introduction of new procedures and application may have to be made for exemption from some statutory regulations (2; 12).

When extreme or special environmental conditions prevail, diving operations should be restricted to one operation at a time so that the back-up and support teams can devote their attentions solely to one team of divers. If there must be separate teams diving at the same time, each team must have its own back-up and surface support so far as possible.

8.2.1. High altitude

Diving at high altitude may be an inevitable consequence of research work in certain regions, e.g. Switzerland, central Turkey, etc. or it may be an aim in itself, with high altitude research dives having recently taken place ataltitudes of around 6,000 m. Diving at altitude requires careful planning and preparation and should not be undertaken lightly. Factors which need to be considered include:

Area: Generally, the higher that one goes, the more remote is the area. This alone can cause problems with logistics, communications and first-aid (e.g. where is the nearest recompression chamber, does one take radios or rely on other communications, etc?). The team must be sufficiently competent in mountaineering, outdoorsmanship and associated survival skills necessary for the selected area.

Logistics: People, equipment and rations have to be moved to and from the diving site. Depending on the remoteness of the site and the type of terrain, movement can be completed in a few hours by vehicle or in days, and possibly weeks, on foot. In addition to personal equipment, diving cylinders, lead weights and other heavy and bulky diving equipment almost always have to be manhandled substantial distances. It is often worth considering the use of non-divers to help transport the expedition's equipment.

Decompression: Altitude diving can be divided into two sections; low altitude (100 m - 3,000 m) and high altitude (3,001 m - 6,000 m). There are no known diveable bodies of water much above 6,000 m.

Table 8-1. Formulae for depth adjustments at altitude.

Low altitude. A simple formula for depth adjustments relevant to decompression for diving at low altitude are provided by the British RNPL tables:

Under 100 m	No adjustment
100 m - 300 m	Add one-fourth actual depth to obtain table depth
300 m - 2000 m	Add one-third actual depth to obtain table depth
2000 m -3000 m	Add one-half actual depth to obtain table depth

This table refers to divers who have previously had at least 16 hours acclimatization at altitude. Other altitude dive formulae are provided by the Swiss tables and by the Canadian DCIEM tables, 1984.

High altitude. No decompression tables seem to exist for diving above 3,000 m. Hennessey (1977), however, recommends the following conversion formula:

$$\text{Depth (tables)} = \frac{2 \times \text{Depth (actual)}}{(\text{Barometric Pressure} + 1)}$$

Note: Barometric Pressure must be expressed in bars.

Only no-stop dives should be undertaken as air decompression schedules on stops introduce an unknown but certainly even greater risk. Specialist advice often may be obtained from diving federations or military agencies in countries that carry out high altitude diving.

Acclimatization: Whenever possible, acclimatization should be carried out for low altitude dives. For dives at high altitudes, acclimatization must always be undertaken. The most sensible approach is a gradual rate of ascent to the diving altitude with sufficient rest periods at intermediate altitudes. A useful rule is: climb high, sleep low. Apart from any acclimatization necessary for climbing, 24 hours should be spent at the dive-site altitude before diving.

Altitude sickness: This is a real problem above 4,000 m, although it has been known to occur as low as 2,450 m. Altitude sickness is preventable by proper acclimatization. All divers on high altitude dives should be familiar with the symptoms and treatment of altitude sickness (Hackett, 1980). It has killed.

Breathing gases: Seek expert guidance on the use of compressed air and other breathing gases at high altitude. Pure oxygen has been successfully used during no-stop diving at 6,000 m altitude. However, very little is known about this subject. Whichever gas is used, do not fully charge the diving cylinders at sea level. Allow for expansion of the gas with decreasing atmospheric pressure.

Ice: Be prepared for ice diving (8.2.2) as ice is often encountered at high altitudes. Preparation means both taking the equipment for cutting through the ice (from hammers to augers and even chainsaws) and, more importantly, prior training in the techniques of under-ice diving.

In general: Sunburn occurs very easily at altitude. Use a good sun lotion and keep the back of the neck covered; a sunburnt neck is not pleasant beneath a rubber neck seal. Neoprene contains bubbles that expand at altitude and this can make a suit unwieldy. Bag-rubber dry suits may be better for altitude diving. Cameras and housings for underwater use are designed to resist external, not internal, pressure. Ensure that ambient pressure can be maintained during ascent to the dive-site (e.g. remove the lens from the Nikonos before ascending).

8.2.2. Polar environments and under ice

Diving has been routinely used on polar scientific expeditions over the past three decades (Fane, 1959; Peckham, 1964; Ray and Lavallee, 1964; Rigler, 1972; MacInnis, 1974; Welch and Kalff, 1975; Horner and Schrader, 1982; Fallis, 1982; Watanabe et al., 1982; Mel'nikov, 1984; Welch et al., 1987), and papers concerned with the detailed methodology for working in this environment are available (Bright, 1972; MacInnis, 1972; Anderson, 1974; Jenkins, 1976; Rey, 1985).

This subsection briefly reviews the essentials of polar cap operations and promotes diving as a safe, effective extension for polar cap aquatic research.

Pre-expedition considerations: Physically and mentally fit, well equipped divers operating with simple, well planned diving practices, maximize the safety and effectiveness of polar operations. Expeditions to either polar region involve rapid transition and novice polar cap divers can be shocked by the light changes, cold and seclusion.

Operational remoteness cannot be stressed too strongly and the diving logistics of an operation, such as equipment maintenance and repair as well as the ability to deal with medical problems, must be entirely self-contained within the expedition. As part of expedition preparation, emergency contingencies should be reviewed, first-aid equipment inventoried and replenished and oxygen supplies secured. On-site medical personnel should be contacted, emergency procedures reviewed and evacuation routes to hyperbaric facilities identified and tested.

Pre-expedition training is strongly recommended. Rutkowski and Ruszala (1980) and Somers (1986) have outlined basic training strategies that can be extended to include equipment and method testing. Program directors should insist that project leaders participate in these exercises so that personal limitations can be identified and dealt with. Frequently, a macho 'we've done it before, it works, no time now, don't worry about it' attitude prevails and over-enthusiastic novices can be lured beyond the capability of their training by 'seasoned' divers.

In addition, most polar projects involve short-term intense periods of activity and the 'part-time' diving scientist must be gently reminded that limits and skills decrease with age and with inactive life-styles. Prior to an expedition, each diver must complete a comprehensive diving medical conducted by a physician who understands the rigors of diving. Pulmonary function tests are suggested for all and an active ECG for those 40 years or older provides an excellent cardiac assessment, promotes fitness awareness and provides a training incentive.

On-site: The success of polar diving operations depends to a large extent on proper selection and use of equipment. Cold is an ever present factor, and divers and surface tenders must be able to recognize the signs and symptoms of hypothermia in themselves and others (8.2.3). Warm, windproof staging areas not only greatly enhance comfort and promote effectiveness but if they are mechanized (tracked vehicles, aircraft or ships), they also provide valuable pre- and post-diver logistical support. During the dive, tenders are especially susceptible to cold, and waterproof insulated mitts and boots must be provided. Frostbite on the face should be watched for and sunglasses should be worn if tenders spend long periods in direct bright sunlight. Post-dive strategies for divers generally involve donning additional outer garments over the dry suit unless under garments are uncomfortably wet. Moderate exercise promotes rewarming as does the comfort of a heated shelter. Fire risk and carbon monoxide poisoning should always be considered whenever a fueled heater is used.

Photo 7: Proper equipment is *essential for successful polar diving operations.* Photo: G. Stanton

Variable volume foamed Neoprene dry suits and thin fabric suits, when combined with underwear, provide excellent thermal protection. The thin fabric, or 'bag' dry suits are less bulky, require less weight and are more comfortable to wear both under water and on the surface. The key to thermal protection is in the selection of appropriate insulating undergarments. Synthetic polyester pile, polyester foam, Thinsulate, polypropelene and wool are available. Because the fabric suits offer little or no thermal protection, extra undergarments are required.

Hands remain the most difficult area to keep warm and until recently, wet Neoprene mittens with snug fitting wrist seals were most common. Now several manufacturers provide wrist ring snaps for attaching dry gloves or mittens directly to the suit. Dry hands greatly improve manual dexterity, comfort and allow longer dive times.

Dry suit hoods are most commonly attached and extra wet suit hoods are frequently used. Air 'double' hoods are available from certain manufacturers and closed foam bonnets can be used under latex hoods. Neoprene face protectors that cover the diver's forehead, chin and lips have been used but they can limit access to the mouth and are not suggested. In recent years light weight surface supply helmets have gained in popularity because wire communications and the extra thermal dry head protection greatly enhances under-ice effectiveness. Scuba, however, is 7most commonly used. There are arguments both for and against the use of full-face masks.

Both single and double hose regulators are used in polar operations and Bright (1972) compares their performance during an Arctic expedition. Under extreme conditions regulator freeze-up remains a problem that can be minimized by keeping regulators warm prior to diving. If the diver does not breathe through the regulator until submerged and then does so in a slow, even manner, free-flow situations can be controlled. To further control free-flow, very dry breathing air should be provided. Because dry air will dehydrate the diver, fluid intake must be increased to prevent decompression sickness.

Double hose US Diver Royal Aqua Master regulators generally have proved to be more reliable than high performance single hose regulators. Dry suit inflator hoses can be attached to the hookah port of the regulator and cylinder pressure can be monitored by using cylinders equipped with submersible pressure gauges attached to the high pressure port of the valve stem. Twin cylinders provide extra air, which enhances safety under ice, and aluminum tanks have proven superior to steel, especially under conditions where restricted base facilities limit washing of equipment. As a safeguard against malfunction, divers can carry a separate pony cylinder with a spare regulator as an emergency come home system. An octopus rig using two separate regulators connected to two take off points on a twin bottle manifold may provide the best safety fall-back for regulator freeze-up.

In addition to scuba and surface supply operations, rebreathers have been used in polar operations. Although cold water decreases sorbant and electronic capabilities, closed circuit systems allow silent, bubbleless,free swimming operations (7.6; 7.8), but maintenance may become prohibitive (Elsey, 1986).

An even further extension of conventional polar diving operations involves the effective interaction of divers and machines. Recently ROV (10.3) and DPV (10.2) systems have been used in polar environments. Although these units now involve considerable expense and operation support, the trend towards light weight and free swim modifications can only enhance their effectiveness.

Water temperature profiles in Arctic sea areas adjacent to major deltas, such as the McKenzie River Delta, or near melting sea ice, introduce hazards to diving. Summer water temperature of about +5°C for the surface waters during maximum water flow from rivers (usually May) decrease rapidly with depth. At depths ranging from 5-30 m the temperature of the sea water is about freezing and below that is sub-freezing. Similar density and temperature profile have been recorded up to several hundred miles away from shore. Water entrapped during descent may freeze at depth. Therefore, preparations for diving in sub-freezing water should be taken in Arctic diving, regardless of the temperature of the surface water.

Surface support: In general, the more surface support available, the better. This applies to both open-water free-swim and sub-ice operations. In open-water operations surface tenders can help stage and recover divers and provide lookout and recall capabilities. A communication method is especially necessary where divers could be injured by drifting ice or marine mammal encounters (8.2.13).

In sub-ice operations, surface tenders form a critical part of the dive team and are responsible for the overall safety of the dive. In addition to actual dive support, tenders are a welcome addition during dive hole production, a task that can be accomplished by melting, augering or blasting.

During ice diving operations, it is strongly recommended that all divers be connected to the surface by a line. Although divers can have their own rope and tender, a very effective way to deploy scientific teams is to have a safety diver attached to the surface and the work diver attached to the safety diver by about 4 m of rope. This arrangement allows the data collector unrestricted access to the task but allows effective communication between in-water personnel and the surface. Hard wire communications via light weight masks or light weight helmets greatly expands this capability and also significantly enhances data documentation and storage.

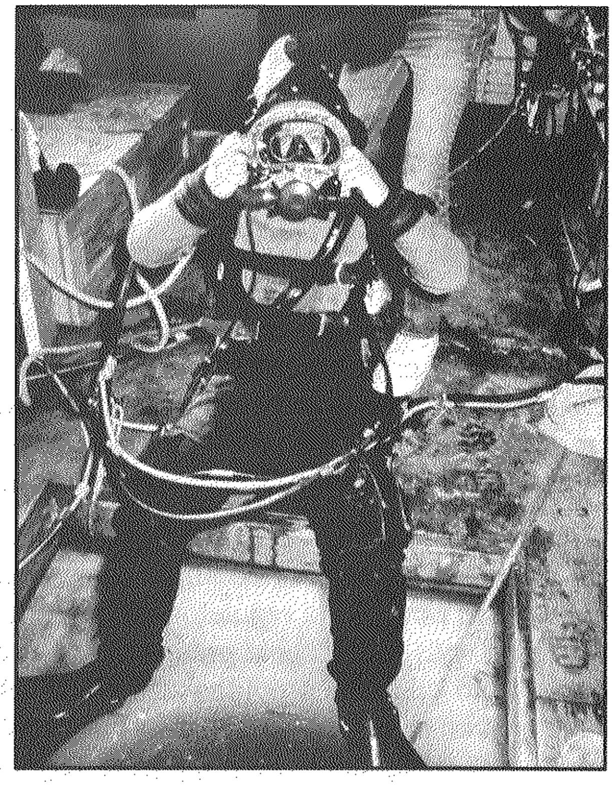


Photo 8: Sub-ice operations demand extensive surface support. *Photo G. Stanton*

Light weight webbing harnesses secured to nylon ropes with two antipodal, non-locking carabiners provide a very positive, yet easily disconnected attachment method. Although free-flow situations commonly occur under ice and dry suit blowups rank a disturbing second in emergency situations, getting lost remains the number one cause of fatality. There is no reason for a tethered diver to become lost under ice but an emergency procedure should be established before the operation begins (Somers, 1986).While a diver is submerged, the tender controls the safety-line and communication is greatly enhanced if the tender is thoroughly familiar with the equipment, procedures and rope signals. Signals (Table 8-2) should be memorized and practiced prior to the dive.

Table 8-2. Rope signals.

	Tender to Diver	Diver to Tender
1 Pull	Are you all right?	I am all right!
2 Pulls	Go down!	Give me slack!
3 Pulls	Standby to come up!	Take in my slack!
4 Pulls	Come up!	Haul me up!

The four pull emergency signal demands immediate attention but on retrieval, care must be taken not to snag the diver on the ice or at the hole edge. If two divers are deployed on one rope, the first diver may have to be pulled clear of the hole before the second diver can reach the surface. Surface support is critical in such situations. Marine mammal/diver interactions at the ice hole have been documented and confrontation for breathing privileges, especially in emergency situations, leaves the diver at a great disadvantage. In open water visual and/or acoustical watch should be maintained for killer whale, walrus, leopard seal and polar bear. In Arctic situations, rifle-carrying local hunters should be advised of free swimming operations.

8.2.3. Cold water

Cold is one of the major hazards that affects divers. Physiologically, cold can produce marked cardiac changes that can be life threatening. In the early stages of heat loss, performance is impaired with fingers and then limbs losing dexterity. Judgement and decision-making processes are affected, with confusion and slowed response a common problem. Behaviour in task performance and problem-solving can be impaired to a point of danger to the diver.

Cold will affect divers differently; some divers are less susceptible to cold than others. There are many conditions that will play a role in cold effects; the major ones are: the duration and depth of the dive, the age and physical state of the diver, the equipment used, the work to be accomplished, water conditions such as current and salinity, and the dive profile. While it is important to concentrate on the immersion factor, it is also crucial to recognize that a major cold stress on the diver is also pre- and post-dive when the diver is possibly exposed to cold air, wind and spray; all of which are significant chilling elements.

Diving in cold water creates problems for diving that can be grouped in two main categories:

1. The problems associated with keeping the divers warm. The physiological aspects can be divided into two categories: a. subtle hypothermia and b. gross hypothermia.
2. Winterizing equipment to function in cold water, and choosing equipment that performs well in the cold.

1. Keeping divers warm

a. **Subtle hypothermia.** A diver's subjective evaluation of his/her thermal balance may vary greatly, and if a heat loss takes place slowly over a prolonged period of time, the diver is more likely to misjudge his/her thermal state than a diver who cools rapidly. Especially in a 'macho atmosphere', divers may tend to suppress the feeling of cold, clench their teeth and accept the discomfort. This typically results in a subtle hypothermia. It is, however, important to recognize heat loss as a problem that is potentially dangerous and renders the quality of the work performed as questionable. Feeling cold is by no means merely a nuisance.

A loss in core temperature of as little as 0.5 to 0.8°C may result in a loss in mental capacity of 10-20% and as much as 40% in memory. Muscle strength and dexterity may deteriorate to a similar extent. Loss of strength is a direct safety hazard, while memory loss and mental slowness can mean that the scientific value of the diver's performance may be seriously degraded.

A slowly cooling diver may gradually go into a state of stupor while feeling reasonably normal. In addition to the effects of cold is the added effect of nitrogen narcosis. If a hypothermic diver is exposed to pressure that he/she otherwise is normally able to cope with, nitrogen narcosis may significantly add to the cold effect and cause an unanticipated reduction in mental and motor (muscular) performance. While a thermally comfortable diver tends to respond to nitrogen narcosis with a relaxed attitude, a hypothermic person will often react with anxiety and claustrophobia and may, depending on self control and training, respond with panic.

b. **Gross hypothermia.** A case of gross hypothermia means a cooling that poses a direct hazard to a person's life by influencing heart rhythm and breathing. If the core temperature drops below about 35°C, cardiac performance becomes erratic. At about 32°C, most persons will be unconscious and will eventually die from cardiac arrest and paralysis of muscles involved in breathing.

c. **Hypothermia, prevention and treatment.** In practice, gross hypothermia is a hazard rarely encountered in diving. Subtle hypothermia is, however, an inherent problem to cold water diving.

Cold requires sufficient thermal protection to avoid hypothermia or to reduce it to a minimum. This can be accomplished by using suits that give either passive or active insulation. Passive insulation means that thediver is protected from the cold by an insulating layer that enables him/her to retain enough metabolic heat to keep warm. Active insulation, or rather active heating, means supplying heat from an outer source like an electrically heated garment worn under a dry suit or supplying heated water to a hot-water suit.

In water down to a temperature of about 5°C, a thick Neoprene wet suit is sufficient for dives of up to half hour duration. It is crucial that wet suits provide a snug fit in order to avoid water circulation inside. A suit with the hood attached to it and a 'long john' trouser is highly recommended. Mitts are preferred to gloves because of better thermal protection. Surfacing divers should be supplied with an appropriate facility to doff suits and change after the dive, such as a heated shelter and protection from wind.

When using suits that give only passive insulation, it is recommended to limit exposure times to 30 minutes and to avoid diving deeper than 30 m in cold waters. Since heat balance depends on the diver's own heat production to sustain thermal balance, lack of activity means faster cooling.

In water below 5°C, a dry suit is called for unless the dive is very short, and unless a heated enclosure is available at the dive-site. Depending on the suit material, more or less insulation will be worn beneath it. Be sure to wear enough weights to be able to descend with sufficient underwear on, taking into account the compression of air and underclothes within the suit with increasing depth. Neutral buoyancy should be maintained by balancing input air on descent with air exhausted at the suit's bleed valve on ascent. A dry-suit diver will normally require from 12 to 20 kg of weights when dressed for cold water diving. A full-face mask may be considered as it greatly reduces heat loss from the face/head. For long dives passive insulation may not be sufficient and electrically heated underwear may be necessary.

Through breathing. The diver may then shut down the hot water flow or report overheating while core temperature is actually dropping. Diving with hot- water suits is strictly surface supplied diving and requires an experienced diving team and topside facilities.

Stage decompression should be avoided in cold water since the diver, passively suspended in icy water, may become excessively cold. Severe peripheral vasoconstriction, that is, constriction of blood vessels close to the skin, will slow nitrogen elimination and render the decompression stop ineffective. If stops are required, the decompression time should belengthened in very cold water. Generally diving tables should be used conservatively when conducting cold-water dives.

If repetitive dives are conducted, it must be appreciated that it takes a considerable time to recover heat balance totally. A practical sign that rewarming is completed, is the initiation of sweating. Do not trust subjective evaluations of being comfortable since the sensation of heat relies more on skin than on core temperature. Heat supplied from an outside source rather than being generated in the body will produce a false perception of being warm again. Normal heat balance may only be obtained after several hours or an overnight rest.

Rewarming of the patient should be prompt but carefully conducted either by placing the subject on a cot or bed with plenty of dry blankets or by immersion in warm water not to exceed 40°C. Rough handling of a hypothermic person poses the hazard of causing more stress than the heart can take and ultimately can cause death by cardiac fibrillation and arrest. Complications may also arise when cold blood from the extremities starts rushing back to the core during the rewarming process, causing the core temperature to drop even more before it starts rising again. Apply more heat/insulation to the torso/head than to the extremities during the initial rewarming to counter this effect. If the patient has stopped breathing, Cardio-Pulmonary Resuscitation (CPR) may be necessary.

2.The technical aspects of winterizing equipment

Every regulator will be susceptible to freezing when used at temperatures below about 4°C. Moisture in the breathing gas condenses and forms ice crystals that cause the regulator to jam. Whether a regulator is likely to freeze depends on the ambient temperature and on the following:

a. Flow of gas produced per unit time.

b. Relative pressure drop of the gas between the various stages from the time it leaves the cylinder until it escapes from the demand valve (second stage).

c. Diameter and shape of the various passageways inside the regulator.

d. Moisture of the breathing gas.

The higher the cylinder pressure, the greater the pressure drop, the higher the rate of flow, the more narrow the routes of escape and the more moisture in the air - the higher is the risk of freezing. Pressure drop causes cooling of the breathing gas below the ambient temperature, however, and a regulator may actually freeze up even if the air/water temperature is above 0°C.

In practice, a freeze-up problem normally starts before entering the water when divers test their regulators in a sub-zero environment. If the air is very cold, ice crystals will form instantly inside the regulator and act as sites for further ice formation during the dive. Water is, of course, always above, or at worst, at the point of freezing of fresh or salt water, and if breathing from the regulator is postponed until under water, the high heat conductance of water will normally keep the regulator abovefreezing. It is highly recommended not to start breathing from the regulator nor to purge it before totally submerged when diving in freezing or near-freezing temperatures.

Since rate of gas flow is crucial to determining whether the regulator will freeze, a slow, careful breathing pattern should be adopted. Divers with a high air consumption are more susceptible to having their regulators freeze than divers with a low consumption. Free-flowing must be avoided since it is likely to cause instant irreversible freezing.

When freezing is likely, cylinders should be filled with as dry an air as possible. Special dehydrating agents in the final filter cartridge might be employed.

If the first stage of the regulator has pressure transducer ports that communicate directly with the water, an anti-freezing cap should be used. This protective cap is filled with an antifreeze such as glycol alcohol that prevents freezing of the pressure ports. Many modern regulators have silicon filled pressure transducers that are not prone to freezing. This feature involving the use of an environmental cap does not protect against freezing inside the second stage of the regulator.

A full-face mask has the inherent problem that a diver will necessarily commence breathing before entering the water and thereby run the risk of initiating a freeze-up problem. It is good practice to avoid prolonged periods of breathing from the mask on land, and it should therefore be the last piece of equipment put in position before the diver enters the water.

8.2.4. Mid-ocean (blue-water diving)

This subsection deals with diving in water whose depth substantially exceeds the depth of the dive, or where visibility is substantially reduced on a dive not approaching the bottom. Diving in the open ocean must be done from a large ship, which is necessary to transport the diving party to the dive-site, with a small dive boat tending the divers in the water.

The most important operational procedure is that no mid-ocean diving operation should ever be carried out without a small manned boat of easy access (preferably an inflatable boat) located on the dive-site and fastened to a vertical shot-line of greater length than the planned dive depth (6.2.7). The shot-line can be stabilized against vertical heave by being attached to a damper disc or plastic bucket at the bottom, or a weight not to exceed 2 kg. Drift of the dive boat may be minimized by using a sea anchor. This boat should be self-propelled (only a light outboard is necessary because of the proximity of the ship), and it should be equipped with a suitable diving first-aid kit and oxygen. Under no circumstances should the ship and the dive boat ever be out of communication, and preferably, sight. The position of the boat should be maintained using the ship's radar.

The primary concerns for a group of divers involved in tasks requiring close concentration are orientation and communication. Even very clearwater is extremely disorienting without a sea floor for reference and extra precautions must be taken to avoid directional confusion or separation. Without a point of reference in the water, divers may accidentally descend deeper than planned; there is also the problem of vertigo that may be induced by the lack of a reference point. These problems are exacerbated if in addition the diver's line-of-sight visibility is hindered by special equipment or poor water clarity.

The methods for rigging lines for blue-water diving are complex and should not be attempted without consulting the original references. It is strongly recommended that laboratories planning to use these methods make direct contact with divers already experienced in the method. For safety and operational efficiency all divers should be attached to light tether lines fair-leaded through clips to a 60 g weight. These clips are connected to a central ring fixed to the vertical down-line. This system allows the tether to be kept taut between the diver and the central ring (Figure 8-1).

In operations requiring more than two divers, one experienced diver should be designated safety diver and should devote the entire dive to monitoring position, air supply and status of the other divers. The safety diver should be positioned at the central dive line and be in reach of the ring holding the tethers for the other divers. Should the need arise the safety diver will be able to attract the attention of any diver by pulling on the tether. The safety diver should

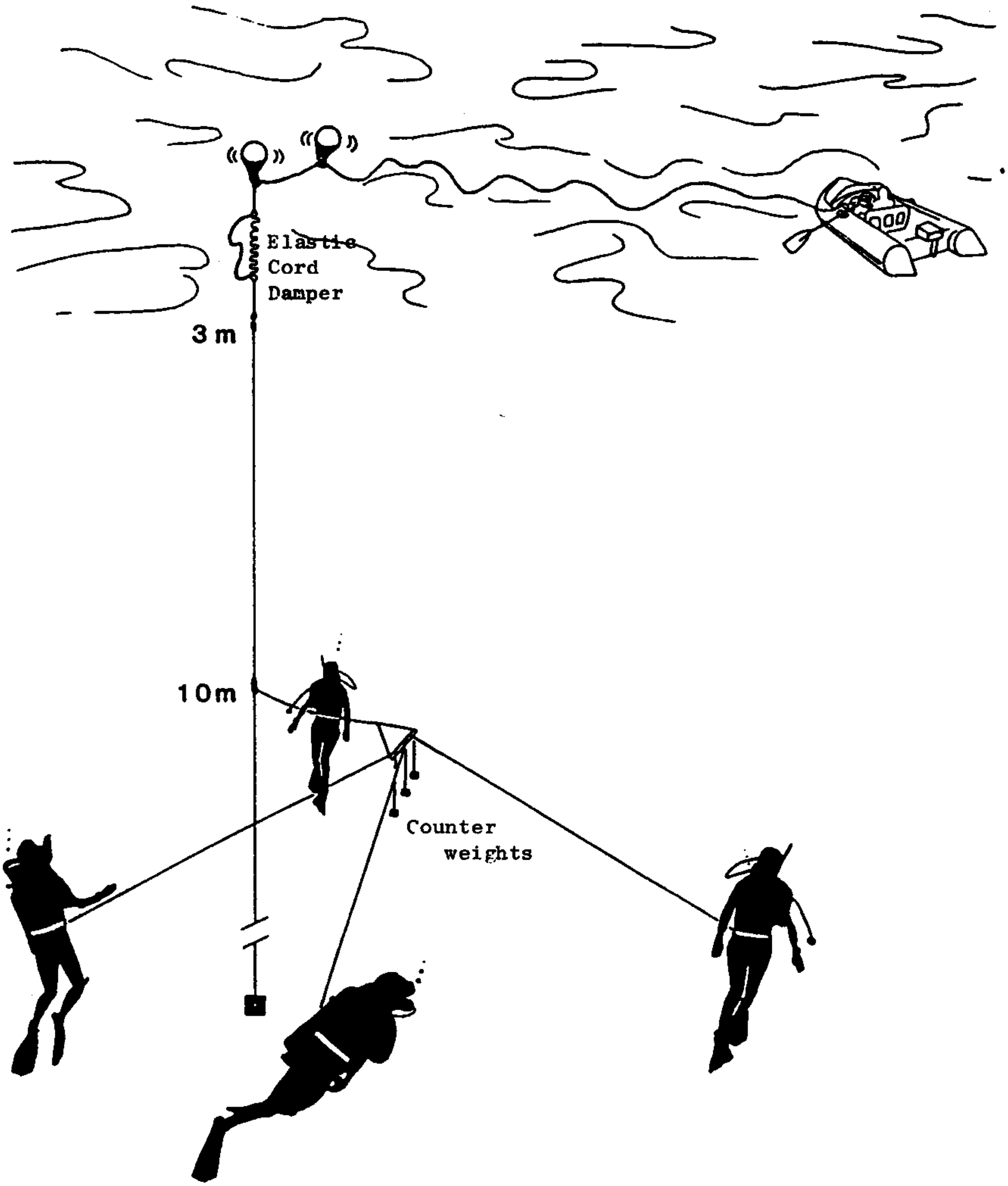


Figure 8-1. Surface boat with operator, down-line array, safety diver and three working divers conducting a blue water dive. Adapted from Hamner (1975).

also be tethered, but on a 1 to 2 m line with a quick-release snap-clip or carabino (Heine, 1985).

The tether lines are needed for communication, and because it is extremely easy in very clear deep water to unintentionally attain a depth in excess of that planned. The tethers serve primarily as a reminder to the divers that they have reached a previously agreed on depth and define the horizontal limit from the down-line. Tethers should never be attached to the diver's weightbelt. At no time should a diver ever unclip from the tether and separate from the group (this especially includes the collection of specimens that always seem to lie just beyond reach).

In event that a shark or other large marine animal such as a marlin, sailfish or swordfish should appear in the dive area it may be prudent to terminate the dive prematurely and exit the water. If, in the judgement of the safety diver or any diver in the diving team an ascent is desired, the divers should unclip, hold the tether in the hand, and move toward the down-line. At the center they should form a circle, release their tethers and move slowly toward the surface. This allows someone to always have observation of the intruding animal(s). Shark billys should be carried if sharks are expected to be encountered.

Even when a recompression facility is available on the ship, decompression diving should be minimized. If in-water decompression is contemplated, note should be taken of the strong vertical shear that often exists in the water at decompression levels, which tends to force divers apart; buddy- lines to the shot-line are essential.

8.2.5. Oceanic coral atolls

The primary hazards that divers normally consider within coral atolls are of a biological nature and involve corals, sharks, stinging and venomous species (8.2.13). There are also physical dangers of abrasion of boat and body against the coral caused by sudden and often unpredictable currents in passes and in the submarine drainage system of the irregularly disposed coral heads. Currents can be induced by tidal movements that are almost imperceptible in open water and by sudden storms which can pond surface water across the atoll, driving submarine counter-currents. In certain configurations of atolls, currents in passes connecting the atoll lagoon with the open ocean are liable to be hazardous and notices to mariners and any available hydrodynamic information should be consulted before planning dives.

Divers can find themselves held against coral or beneath a water-cut overhang by current or waves. There are extreme differences between sea-state in the sheltered waters of an atoll lagoon and the surrounding open ocean. When approaching the fringing reef from the inside of the lagoon, sudden and violent surf action can be encountered. Sea-state in passes directly open to the ocean may be high, even if well into the lagoon; small boat transits across these passes may be hazardous.

Freshwater will often be found in the upper part of the water column in an enclosed atoll after a period of rainy but not necessarily windy or stormy weather (much of the rain on an atoll is adiabatic and is caused by local weather systems which are driven by heated air rising directly above the atoll and forming rain clouds when cooled off at altitude, rather than frontal system storms). The freshwater will cause haloclines with poor visibility in the turbid water at the interface and there may also be thermoclines. Water movement below a water interface is often quite different than above, and if a diver penetrates into a body of water moving more rapidly, he/she should ascend so as to not be swept away from the other divers.

8.2.6. Coral reefs and fringing reefs

Most coral and fringing reefs are situated in equatorial areas that are remote from major population centres and the usual support services. Locally, however, these reefs of interest are near small ports and, sometimes, diving services. Medical treatment may not be readily at hand. Even the closest reefs to Townsville, the largest population centre in proximity to Australia's Great Barrier Reef (8.2.15), are beyond the permitted operational range of local rescue helicopters, but many of the Red Sea, Caribbean and South Pacific reefs have local access.

It is important to minimize and prevent infections and/or tropical ulcers. Treat all cuts promptly no matter how small or apparently insignificant they appear. Some folk wisdom suggests a course of vitamins, especially vitamin C for a period of time (10 days) before diving to strengthen the body's immune system. Heat rashes and fungal outbreaks may be troublesome and should be treated promptly.

Divers should be familiar with the appearance and habits of dangerous animals, which can be encountered on and around coral reef systems. Treatment can be very specific (Edmonds, 1975).

As part of dive planning from shore, small boat or large boat, access to a reef system, entry and exit conditions need to be considered (6.2.5; 6.2.6; 9.2). In areas of high tidal range, the changed tidal level between entry and exit time must be taken into account; divers can find themselves with a very long and difficult walk over jagged live reef at low tide. During the course of a dive visual contact should be maintained between divers as the use of tethering ropes in the coral environment is not always practicable.

The seaward face of a coral atoll, a barrier or fringing reef contains all of the hazards attached to diving around coral elsewhere, but in addition there are several hazards particularly associated with this environment. The primary danger is that of very rough seas suddenly rising up at the reef edge where an often eroding margin gives way suddenly to a vertical drop. This is because the face of a reef is characteristically steep, plunging away to great depths from the shallow coral reef bank. This steep slope, which is often undercut as a result of local changes of sea level, acts as a wall to the movement of water and even without much wind, breakers can suddenly form on the reef margin with the impingement of swells that can otherwise be undetected on the open-sea surface. If divers are down on the reef face, they can become involved in the underwater surge of water associated with the disruption of sea swell at the reef face in addition to becoming suddenly enmeshed in rough seas on surfacing at the pick-up boat. Divers must be prepared to swim to seaward, possibly underwater (while towing a buoy for the boat to follow) in order to find calmer water for pick-up.

Most incidents around reefs involve cuts and abrasions from the extremely sharp surfaces of the growing coral; edges of shell can be as sharp as a knife. Dead coral is not as sharp or abrasive.

A secondary hazard is that sharks are commonly found in the deeper water off the reef face. They are attracted by the same often rough water that is responsible for disturbing the coral at the margin of the reef and providing abundant food supplies (8.2.12).

Note that many coral and fringing reefs are given a level of statutory protection by governments. This may take the form of protecting corals or other specific groups of organisms, requiring general permits for scientific collecting or research, imposing certain bag limits or prohibitions of certain collecting methods, or the entire area may be contained within a marine park over which a range of rules and regulations apply. Ascertain, as part of the dive planning, the nature of any restrictions or permit requirements, and ensure that these have been fully complied with.

It should also be remembered that because of the generally good water clarity around reefs, visual techniques can often be used rather than those relying on actual collection of specimens. For example, visual census techniques have been developed for a variety of fish (Anon, 1979a; 1979b; Reese, 1981; Craik, 1982), crown-of-thorns starfish and their feeding scars (Done et al., 1982) and coral and other invertebrates (Stoddart and Johannes, 1978).

8.2.7. Surf and rough seas

The surf and nearshore zone is the most dynamic and one of the most extensive and common marine environments encountered by divers. It is an area where waves and tides expend much of their energy; where most littoral sediment transport occurs; where problems such as coastal erosion and accretion have their roots; where macro- and meiofauna are becoming increasingly recognized for their role in marine ecology. It is also the most readily accessible and best known part of the ocean as well as one of man's favoured areas for recreation. For these reasons and many others, a thorough knowledge of this zone is required to manage the increasing pressures placed upon it.

Surf type: Identify what type of surf zone is likely to be encountered, particularly the wave and tide conditions expected. There are three basic surf zone types:

1. Reflective beach and surf zones are formed by long low waves and/or very coarse sediment. They have steep plunging breakers in a narrow but powerful breaker zone. Careful timing and quick movement between wave sets is required for entry and exit. The nearshore zone extends close to the beach/breaker zone, and dive boats can safely anchor close inshore.

2. Intermediate surf zones (moderate energy) are characterized by rips and transverse to shore parallel sand bars. For entry to outer surf zones use rips, for inner surf zones use bars or rips. For exit use bars or zones of breaking waves, but not rips. The nearshore zone extends to the outer bar. During low waves the dive boats can be placed in longshore trough or rips with caution. The divers must check the overall pattern and swash of bigger waves sets before entering the surf zone in boats, keeping to 'calm' trough water with the boat's bow always into waves while using the engine to manoeuvre sideways and backwards by expert use of the engine. Move the boat swiftly when crossing bars.

3. Dissipative surf zones (high energy and fine sand with wide breaker zones) tend to have vertically segregated flow. For entry and seaward travel it is best to use the seaward pulsing (30-90 seconds) bed flow. For exit and return to the shore use surface wave bores. The wave breaker zone is usually wide (100 m plus) and highly transitory. Be very cautious when approaching from seaward as the larger sets of waves break 10's to 100's of meters further seaward than the main breaker zone.

General hazards to be prepared for:

1.Low to zero visibility, especially as breakers and wave bores pass over.
2.Bidirectional wave oscillations, especially seaward of break point.
3.Unidirectional longshore, rip feeder and rip currents which usually pulse at 30-90 second intervals. Use these currents to your advantage, do not try to swim against them.

4.Swim out close to the seabed avoiding surface turbulence and shoreward flows; to return, surface and allow wave bores to wash you ashore (avoid rips).

Equipment deployment: When deploying experimental equipment in the surf zone place a surface piercing ship antenna on top that will break the water surface to permit location from shore, buoy and weight appropriately. Attach a weighted line from equipment to shore or boat. The weighted line can be used to relocate by following along the seabed. To recover equipment, divers can hold equipment off the bed or float it to the surface while others use the line to pull it ashore or onboard.

Scuba equipment:

1. Keep equipment hydrodynamic.

2. Minimize extraneous gear such as cameras, note boards, etc.

3. Secure all gear as tightly as possible, both personally and in boats.

4. Overweight at least 3 kg to stay on the seabed; because of the shallowness in surf zone, divers can use their buoyancy vests to surface readily.

5. Be prepared to have your face mask knocked off or down (often), hold on when necessary. The regulator is rarely pulled out of the mouth; fins commonly are pulled off, but usually only one at a time. Divers might consider lashing their gear to life jacket straps for security; tying to weight belt is not a good idea as the weight belt must be ditched quickly if the diver starts to get into difficulties. Loss of weight belts is a common event in surf-zone diving.

6. Because of low visibility and turbulence, diving buddies must be very competent and physically quite fit to keep in contact and carry out their research.

Nearshore, above wave base:

1. Make sure that the dive boat is safely located (see surf type), especially outside intermediate and dissipative breaker zone.

2. Because of low visibility and strong currents, tie off all equipment lowered overboard; also there should be a line to divers either from the boat or a buoy. The boat should trail a boat safety-line and buoy.

3. Be prepared for wave orbital motions at bed with to and fro horizontal movement of up to 5 m and plumes of suspended sediment. It is best to go with orbital currents rather than fight as they return you close to where you started. If the diver has to remain in place, overweight and hold on to the seabed (dig in knife) or base of equipment (avoid the top of equipment as the diver may pull it over or break it, especially cables).

4. If working, wait for lulls in between wave pulses to do work, then lie low during pulses.

5. Plan the dive and dive the plan but be prepared for contingencies.

6. In nearshore repetitive diving, start deep and work into shallow water

Limits: There is a limit to scientific work in the surf zone and nearshore. A general rule is when you have little or no control over your direction of movement, then it is time to get out. This can occur under relatively low waves on some reflective and intermediate beaches especially in the rip channels. Examine the surf carefully and if necessary swim out in snorkel gear to check currents before attempting scuba. Finally the divers must be competent surf swimmers who know how to use waves before attempting surf scuba. The waves and currents are there to be used for offshore, along shore and onshore transport; plan your dive to use the current patterns and never try to fight against them. If in difficulty the diver should surface immediately and always approach the shore on the surface.

8.2.8. Fast currents

Conditions of rapid water flow are extreme for divers when the water is moving at a greater rate than a diver can comfortably make way swimming, commonly one knot. The greatest danger of diving in rapidly moving water involves being swept offshore or along shore into hazardous shore areas, especially if there is no boat cover. Becoming separated from a boat while diving further offshore is not quite as dangerous as the diver can usually be found in open water, especially if flares and fluorescent patches are carried. Water movements on the surface may be very different in direction than deeper and bottom water. Surface water currents are usually greater than those on the bottom and without a surface buoy to indicate the divers' position, separation is almost inevitable. Tracking the diver by watching for bubbles from a boat on a choppy day during a deep dive must not be relied upon.

Diving in currents should usually be done while the buoyed divers are covered by a manoeuvering boat. Diving down an anchor line, which is occasionally necessary to procure specific specimens, puts the divers in very high drag situations and physical strength and endurance is important.

Each diver should be as hydrodynamic as possible so as to be least affected by water drag. Masks should be low volume and the snorkel should be held in knife strap and bootee or inserted across the crotch strap as the current drag on a snorkel affixed to the mask strap can pull off a mask. Short, broad fins are more manageable than long speed swimming fins and strap-fins are better than shoe-fins as they can be more easily refitted and secured. Instruments should be low profile and snag resistant as the diver is often swept into weed and ropes. Back-pack bottles increase water drag, are difficult to get off and on rapidly and are particularly liable to foul as they are held away from the body. Bottles held tightly to the body are inherently better in a current, and these bottles, without a back pack, also stack and can be secured more easily and safely in small boats in rough water.

It is advisable to use ropes and shot-lines on all dives in fast moving water. In its simplest configuration, the fast-water rope set consists of two lines (6.2.7).

1. A shot-line (also known as a down- or main-line) is the line connected to a buoy at the surface and an appropriate weight or anchor at the bottom. In very rapidly moving water that will drag down even a large surface buoy, only enough weight to keep the bottom of the line dragging on the bottom should be used. This avoids the diver being exposed to uncomfortable or dangerous drag while ascending the line and possibly making stops. Moving with the water rather than fighting it is inherently safer. This line should be only up to about 50% longer than the water depth, and the more vertical it can be kept, the better, although length depends entirely on the size of the buoy and current speed. Divers should descend by hooking an arm over the line, facing into current and by tilting the body downward allows the current to hydrofoil the diver down the line. To ascend the diver faces into current, hooks an arm over the line and finning or with buoyant assist, tilts upward and allows current to drive him up the line.

2. A sweep-line, which is deployed by the divers after reaching the bottom, is for horizontal travel from the base of the shot-line. This line is usually about 10 m long and allows the divers some freedom of movement in a radius around the bottom of the shot-line. The shot position can be changed underwater by the divers to provide for greater area coverage; divers may swim the shot-line weight and drift with current to get to a more suitable location. Of the diving team, the buddy should always be further out the sweep-line than the 'scientist'. The scientist usually is in charge of determining the sampling or observational position and the rope-diver assists. The buddy, who is usually not as totally preoccupied with the science, is primarily responsible for the dive safety.

8.2.9. Night diving

Diving at night is becoming increasingly an operational requirement in scientific diving. To divers coming into night diving from a background of sports diving, this may cause some concern, though it may be a comfort to know that almost 50% of all commercial diving operations are carried out at night and these incur few problems for the diver.

Pre-dive: Lighting. Adequate light should be available for the surface team to work by. When using hand torches (flashlights), avoid shining them around as it upsets night vision. Surface cover. Ensure a fully working surface cover boat. Markers. Where possible (and certainly in complex jobs) jackstays, marker panels and guides (6.2.7) should be rigged to aid the diver. In less complicated tasks, a simple shot- or main-line leading directly to the job will often suffice. Briefing. The diving team should be thoroughly briefed on the task, including routes to and from the job, leaving and entering diving platforms and safety procedures. Briefing is more important than on day dives as the dive team members must be able to anticipate the actions of other divers without being able to observe them.

On-dive: Safety. Whether to use the buddy system or a life-line will depend on the circumstances. A life-line can often be the better system for scientific diving at night. It gives the diver a psychological boost and,more importantly, gives him a line of communication with topside. In the event of difficulties, it gives the standby diver a direct route to the diver. Light. Many divers are surprised the first time that they dive at night at the amount of available light that exists underwater. The moon and stars are the main source of this light and, once the diver has obtained night vision, visibility can be quite good with no artificial light. This, of course, assumes little water turbidity. Despite the possibility of good underwater vision, each diver must still carry at least one torch. Good quality, lightweight underwater torches/flashlights are now available. An excellent emergency light is the chemical 'Cyalume' or 'cool lite' lightstick. They work equally well underwater and topside and are unaffected by pressure at least to 50 m depth.

Post-dive: Safety. Locating and recovering a diver at night is not always easy. Extra care should be taken, especially if decompression is involved. Thought should be given to rehearsing diver recovery procedures during daylight. Clothing. Heavy-duty windproofs should be available for divers leaving the water to keep the chill away and allow them to continue participating in the scientific aspects of the project.

8.2.10. Kelp and other seaweed

Kelp is a collective term for a number of species of macro algae which form large underwater three-dimensional systems similar to forests. The distribution is worldwide in cold to temperate seas (0-16°C), in a depth range of 0-130 m. It often occurs in a high-energy environment where it has the effect of attenuating wave action. As a result of this sheltering effect and also being a primary producer of high output, it harbours a complex community of organisms which could not exist without it. Many scientific projects involving underwater physical and chemical oceanography and ecology have been conducted in this environment in the past and more will continue in the future.

Guidelines:

1. The shelter afforded by many kelp beds from sea and swell may be used to advantage in launching diving boats or for divers to gain access to the sea on an otherwise exposed coast.

2. Certain species of kelp, such as Ecklonia maxima produce a dense canopy at the surface. When diving at low tide the canopy tends to pack tightly making penetration difficult. This can be a danger, particularly to the novice, when diving with a snorkel only. Windows usually occur in canopy cover; these may move or open and close with passing swells. This must be taken into account when planning a return to the surface. Forcing a way through the canopy should be avoided as invariably mask and snorkel end up round the diver's neck. Novices to kelp diving should be adequately briefed before entering the sea. Diving at high tide is usually easier.

3. A knife worn on the outside of a leg is liable to snag on kelp plants, resulting in entanglement or loss. The knife should preferably be worn on the inside of the calf.

4. Buddy-lines may be dispensed with because of the problem of entanglement. However, strict discipline in buddy contact should be enforced. Towing a marker float in kelp is usually not possible, although using a shot- and sweep-lines (6.2.7) is often possible to get below and operate below the kelp canopy.

5. Kelp may snag the air reserve rod on the air bottle resulting in either a bent rod or premature switching to reserve. This can be avoided by substituting a cord and toggle to activate the air reserve or by training divers to reach up and behind to activate the toggle directly. It is preferable in many cases to use cylinders that are not fitted with the J-valve.

6. Because kelp usually occurs in cold water, hypothermia may become a problem.

8.2.11. Pinnacle and seamount diving

Pinnacles are a worldwide feature found in both coastal and oceanic situations. They are characterized by their relatively small surface or near surface area and steep sides. They include rocks of both sedimentary and igneous origin. They are of particular interest to physical and chemical oceanographers, geologists and biologists. Often their isolated situation provides for interesting community and genetic studies.

1. With steep sides, small upper surface area and often rugged topography, anchoring may be difficult. A shot-line of 13 mm diameter synthetic fiber attached to a 25 kg anchor weight and buoyed by a float of 50 l displacement is recommended for mooring a small boat or an inflatable carrying divers. Care must be taken that the anchor weight finds bottom and that there is sufficient slack in the line so that the anchor does not drag off the edge of the upper surface.

2. Currents of 50-100 cm/second may be encountered. A 50-100 m trailing-line (6.2.7) should be streamed from the shot buoy for a diver to grasp in the event of surfacing away from the shot-line. In oceanic situations working from a large research vessel, a diver can be swept from sight in a short space of time (8.2.8; 8.2.15). Often this type of diving involves deep

diving where there will be one or more decompression stops. A master compression chamber with trained supervisor in attendance and a medical practitioner specializing in diving emergencies should be available on the research vessel.

3. Ships tend to swing at anchor. If diving takes place from an anchored vessel there should be lookouts placed on either side. Currents further increase the uncertainty of where a diver will surface.

4. Water clarity in the vicinity of seamounts is usually extremely good. Judgement of depth is therefore deceptive. The shot-line should be clearly marked at regular intervals for depth but well calibrated depth gauges should be worn as shot-lines are very rarely vertical in the water.

5. Pinnacles, particularly seamounts in deep-water situations, usually attract sharks. If decompression stops are envisaged and sharks are present, a shark cage must be provided for protection at decompression stops. All divers must receive full training in shark cage use before work dives are undertaken 8.2.12; Appendix 2).

8.2.12. Sharks

Although attacks by sharks on divers do occur, most sharks do not present a hazard. However, all sharks should be treated with respect. Sharks are found generally in the deep open ocean, but tend to be concentrated where localized shoaling water occurs, such as over seamounts and ocean ridges and seaward of coral reefs. As it is often these features which divers investigate, the chances of encountering sharks under oceanic conditions are good. In many areas of the world such as Australia and the Pacific islands, however, dangerous sharks do come into shallow water even up to the shore line. Sharks in enclosed spaces appear to act similarly to their actions in the open ocean (8.3.13).

1. Divers should operate in pairs. This affords a better opportunity of detecting sharks at a distance before they become a threat as sharks often approach by circling prior to an attack.

2. When the possibility of shark encounter exists, one or both divers should carry either billys or electric shock rods. Not only do they offer a reasonable measure of physical protection, they also do much to reduce tension in the divers. Provocation of sharks should be avoided as this can be a reason for a shark attack.

3. Fishing in the vicinity of a diving operation should be banned at least for the crew members of the research vessel, and for nearby boats if possible. The collecting of fish for scientific purposes by divers should be avoided in shark infested water. If fish are taken, however, they should be attached to a float and towed some distance away from the divers.

4. The dumping of scraps or rubbish by the research vessel before or during a diving operation must be avoided.

5. An injured or bleeding diver should leave the water immediately; other divers might also exit the water for a period of time following any blood in the water.

6. If a shark shows more than a passing interest in a diver, the diving operation should be aborted; it is advisable for the divers to return to the boat in as calm a manner as possible.

7. With dives involving decompression stops, either a multi-person, double lock compression chamber must be on hand or a shark cage must be attached to the shot-line at the first decompression stop. The cage should be capable of being moved upwards from stage to stage

by the divers inside. All divers in the team must be given adequate training in entering, exiting and manoeuvering the shark cage before work dives are undertaken.

8. Many sharks are nocturnal feeders and during feeding are often found in shallower water. Night diving should thus be avoided if possible where there are sharks.

9. If explosives have been used to obtain rock samples, or for any other reason, diving should not take place immediately afterwards in case the dead fish attract sharks.

8.2.13. Dangerous marine animals (other than sharks)

Most dangerous marine animals other than sharks occur in tropical water and are often concentrated around reefs. Similar dangerous animals are also found in temperate waters but there they are usually related species that may only inflict painful stings rather than being life-threatening.

Marine life recognition and injury prevention techniques are not discussed here as these are commonly subjects in their own publications or extensive chapters in manuals (Somers, 1972; Appendix 2). The standard international reference for dangerous marine species is Halstead (1976). The objective of this subsection is to briefly describe the general injuries that can occur and to warn about certain species. Injuries that can occur to divers include:

Stings: Most animals that inflict injury by sting are Coelenterates which include hydroids, fire coral, Portuguese Man-of-War, jellyfish, box-jellyfish or sea wasp, and some common corals and anemones. Stings are administered through many stinging cells of the tentacles. Symptoms range from mild discomfort to a stinging sensation and a throbbing pain that may render the victim unconscious. Death can result in severe cases from respiratory and cardiac arrest. In the case of fixed stinging animals, the diver must be wary in his/her approach to rock or coral surfaces and remember that the stinging cells can be brushed off onto the wet suit, equipment or samples and are still capable of stinging long after the encounter with the host animal. In the case of free-swimming forms, such as jellyfish, divers should keep their attention focused up current as these animals drift with the current. During an ascent when stinging jellyfish and other animals are likely to be encountered, at least one of the divers should turn in the water while looking upward and watching for the dangling tentacles. Care should also be taken to examine the shot-line if it is used by an ungloved hand in the ascent as stinging cells from tentacles could have been deposited on the line by a passing jellyfish. Not all jellyfish sting and it is important that if the diver becomes enmeshed suddenly in a tangle of jellyfish tentacles, as sometimes happens in temperate waters, that they are removed with calm, deliberate actions rather than in a panic which may introduce an accident in its own right, or accelerate any potential irritation from stinging cells by causing more to come into contact with the diver. Some sponges will also produce skin irritation and in some cases, symptoms similar to non-fatal jellyfish stings.

Venomous puncture wounds: These may be inflicted by stingrays, cat- fish, weeverfish, scorpionfish and other kinds of venomous fish. In all cases the diver has to have been stung by touching venomous spines on these fish to obtain an injury. The pain from venomous fish sting is usually immediate, intense and can be sharp, shooting or throbbing. Pain radiates from the affected area. Extreme cases involve unconsciousness and possibly cardiac arrest. The only advice that can be given, as most of these fish hide buried in sand or camouflaged on rocky and sediment bottoms, is that the divers must be very careful how they proceed. These fish will not usually attack, except for possibly a short rush toward the diver of less than 1 m when the diver comes closer than the fish can tolerate. Slowprogress and use of a stick to prod sand and suspicious areas can often expose these fish. When descending, it is good practice to make contact with the bottom fin first and to use the fins to prod the bottom.

Venomous bites: Venomous sea snakes and the blue-ring octopus are a particular threat to divers in Australian and Indo-Pacific waters. At present, there are no reports of sea snakes in the Caribbean or Florida Keys. At least one species of sea snake, however, has been found in the Gulf of California. Octopus bites are very rare and no reports of fatalities from octopus bites are known from the Caribbean or Florida Keys.

Sea snake venom is approximately 2-10 times as toxic as that of land snakes. However, they deliver less of it and only about 25% of those bitten by sea snakes show signs of poisoning. There may be no pain or reaction at the site of the bite but symptoms which develop quickly range from an ill feeling or anxiety to muscular stiffness. Late symptoms include shock, weakness, muscle spasms, respiratory difficulties, convulsions and unconsciousness. Deaths have been reported. Sea snakes swim quite quickly and can often approach a diver apparently out of inquisitiveness. An approach should not be considered necessarily as an attack. Calm withdrawal from the vicinity of sea snakes is recommended.

Non-venomous bites: The moray and conger eels, barracuda and shark can inflict tearing jagged type lacerations. The shark bite is generally most serious and often requires dramatic first-aid procedures to save the victim's life. Relatively minor bites, such as those of eels and barracuda require first-aid procedures for lacerations. Eels generally are found in enclosed spaces and holes and probing these areas is recommended before exploring with a hand or more of the body. Free- swimming fish attacks are often difficult to predict as these fish are known to attack without provocation and exiting from the water is recommended if there are not forms of protection such as shark cages, etc. (8.2.12).

Conclusion: Prevention of injuries is the best policy. Do not handle marine organisms that you are unfamiliar with, and do not take chances with those that you know can inflict injury.

8.2.14. Diving near very large animals

Very large animals such as large whales, fish, reptiles and seals are rare. Diving with them either by choice or by accident is an even rarer, often once-in-a-lifetime experience for the majority of divers who are in the right place at the right time. Very large animals are potentially dangerous because even if they are not actively aggressive, their sheer bulk, power and agility can result in accidental injuries, and so even the most docile should be treated with caution to ensure that this unique experience isn't a final one for the diver. Remarkable films have been shot by divers working with sharks, dolphins, seals, polar bears, grey whales, hump-back whales, Wright whales and even briefly with a blue whale. These records provide some visual reference material on behaviour and attitudes to divers.

Learn as much as possible about the habits of the species concerned and plan the dives and support accordingly. Appreciate that behaviour can change seasonally and in addition, many species are more aggressive during their breeding season. For example, seals such as fur seals congregate in large coastal colonies to breed. The bulls ferociously defend areas on land in which to hold harems. In these circumstances, it is often possible to swim with hundreds of adults in the sea only to be attacked when leaving the water. Other normally placid seals, such as Weddell Seals, can be more aggressive in the water since they may defend breathing holes against intruders, and males drive off competitors near to groups of females during the breeding season. It is therefore important to know something of the characteristics of the species encountered before assuming that experience with related species is adequate to ensure safe procedures.

Very large animals have few natural predators and so they will have little or no apprehension of humans in the water. Indeed they are quite likely to approach divers from curiosity. Remember that even normally docile species can become aggressive when they perceive that they are cornered, if their young are approached or if you infringe their breeding or feeding territories. Chance contacts with very large animals are impractical to plan for, and therefore a diving group depends on its former training to react appropriately to the circumstances. Dive supervisors and marshals must appreciate that such events have strong psychological effects, and that previously reliable divers can often react in an unpredictable manner. If an accidental meeting occurs, the safest action is to leave the water quickly. Care should be taken to avoid excessive haste because this can provoke a pursuit or attack reaction in active predators such as large sharks and toothed wales.

When deliberately planning to dive with large animals, divers must:

1. Plan the dive, equipment and support in accordance with the animals which are anticipated to be encountered.

2. Plan the dive, equipment and support appropriate for the locality. Remote sites will require more extensive support and planning.

3. Ensure surface craft are of an appropriate type to withstand buffeting and biting!

When diving with large animals, divers should:

1. Treat all large animals with caution (8.2.12; 8.2.13; 13). Take particular precautions with large, active predatory sharks, reptiles, toothed whales, seals and bears.

2. Avoid diving in low visibility water.

3. Take advice from local divers and fishermen.

4. Study the available information about the behaviour of the species anticipated.

5. Not feed large fish. They learn to associate divers with food and become aggressive if not fed.

6. Not use aggressive methods to control large animals except as a last resort. If large animals, particularly mammals, learn that divers are aggressive, then this can result in unprovoked attacks.

7. Not encourage play activities. This can also lead to attacks.

8. Avoid diving in enclosed areas such as sluices, fish traps and purseseines.

When a large animal arrives in the presence of divers unexpectedly, the divers should:

1. Leave the water as soon as possible.

2. Review the potential hazards and only return to the water if safe to do so.

8.2.15. Diving in remote locations and on coasts of difficult access

A remote area is one where the population density and boat traffic is so low that the occupant of a diving boat stranded away from the main base would have no real chance of being picked up or of receiving food or assistance of any kind. Equally the base camp is assumed to be so isolated that in the event of a serious accident it would take days rather than hours to get the injured person to a good hospital.

In remote areas medical, rescue and recompressing facilities are generally absent. The diving program must therefore be conducted in such a way that these services can never be required. All equipment should be kept as simple as possible to reduce problems with breakdowns and maintenance. If complex equipment must be used, the fullest possible spares kit and repair tools should be carried, and a member of the group should be fully qualified in making repairs.

Even when a dive-site is not remote in a geographical sense from human habitation, it may have difficult or limited access from the landward side due to cliffs, dune fields, desert, strong currents or wave action. The main concern of a diving supervisor is the ability to deal with an emergency situation involving an injured diver. With difficult or restricted landward access, a diving operation is usually undertaken from the seaward side by boat. Should seaward access be restricted as well, emergency planning must be carried out in advance. Arrangements should be made in advance with whatever army, coastguards, police or private interests that may be better supported logistically in the area to help get an injured diver to a doctor or hospital.

A member of the team should have specific responsibility to ensure that the boats contain working flares, dye markers, hand-held bearing compass, radio, survival packs, drinking water, and other items determined by the region and logistics. There should always be a stock of food on board. There should be at least two serviceable boats on the working site except when operating very close to base. When a single boat is in operation, a spare engine should be carried (6.2.5; 9). For longer trips two boats should travel in convoy. Radio contact should be maintained between boats and the base camp at predetermined intervals in addition to potential emergency calls. Keep within anchor depth where feasible especially when there is an off-shore wind or tide and carry a sea anchor. When anchoring on reefs remember that a fouled anchor is likely and plan for enough sparediving time to allow a diver to free the anchor. More general recommendations on small boat operations and the use of some boat equipment is given in section 6.2.5.

Local boatmen are usually reliable about local surface conditions. Do not trust them about underwater conditions, unless they are actually divers and then be prepared to consider their suggestions while remembering that their experience probably was gained while carrying out commercial operations. Patiently make inquiries from likely locals when in an area but do not appear to interrogate them as this may make them less than happy about your presence. Members of the party should go out of their way to help local fishermen and watermen in such matters as clearing their propellers. Actions of this sort will be remembered.

Medical supplies should be extensive and of a far more complete inventory than would normally be kept during a project in a non-remote area. At least one member of the team at each dive-site should be qualified to use them. The presence of a paramedic or doctor is advisable.

8.2.16. Negative altitude diving, surface below sea level

This section is based on experience and procedures used during research diving in the Dead Sea with a water surface at minus 400 m. Tables were not recalculated although checking by using negative figures in Hennessey's calculation (8.2.1) indicate that these a priori procedures might be safe, assuming that the calculation is true for negative values (not proven for negative values). Formulation of air decompression schedules below sea level has not received the same attention that table modification has for diving at high altitudes.

The higher atmospheric pressure at the sea surface as well as the higher density of the water had to be taken into account in the decompression rates. Therefore physical depth below sea surface was ignored from the point of view of assembling a new table or modifying an existing table by interpolation; the dive and the decompression stations were planned relative to ambient pressures. The tables used for planning the dives were the standard US Navy Decompression Tables. However, all dives were assumed to be decompression dives requiring at least a 3 minute decompression stop at the pressure equivalent of 2 m below 'normal' sea surface. Moreover, the selected decompression schedule corresponded to the next deeper and the next longer bottom time beyond that which would have been selected in normal circumstances. As a result, in the course of 48 dives, only one slight mishap, which could as well be ascribed to tension and exhaustion rather than to a decompression incident, was encountered.

A peculiar aspect of negative altitude diving is that surface travel home after a dive or a series of dives might involve the same risks as flying after a dive. Traveling to a moderately higher altitude (< 1,000 m) should probably be postponed at least until an appropriate length of time has passed to wipe out a nitrogen excess for the purposes of repetitive diving (6 hours for USN Tables, other tables differ). Traveling to analtitude greater than 1,000 m above the dive-s greater than 1,000 m above the dive-site surface should be made with reference to flying after diving (11.5).

Aspects of diving in saline lakes in desert areas, while not common to all diving sites with water surfaces below normal sea level, are common enough to warrant comment here. High ambient air and water temperatures, low humidity, lengthy prepartaions before a dive, the difficulty and the effort necessary to move about and enter the water carrying the heavier weights necessary as well as the effort necessary to swim to the diving point led to large energy expenditiures even before the dive began. These factors could induce heat exhaustion, hyperthermia and dehydration as well as breathing difficulties and hyperventilation underwater, (8.2.22). These factors in turn can increase the chances of decompression sickness (11). Hence equipment was not put on until the last possible moment, movement was curtail to a minimum and the divers were requested to drink large quantities of water. Although electronic communication between divers and the surface allowed for greater safety, voice communication was seldom used between divers.

8.2.17. Diving in low and zero visibility

The diver's ability to orientate and navigate correctly is much reduced in low and zero visibility conditions. There is a danger of the diver unknowingly becoming placed in a hazardous situation from which extrication will be difficult without assistance from another diver or the surface. Specimen collecting can also introduce hazards to the diver and his/her assistant, e.g. geologists with hammers and biologists with nets or core samplers. The presence of potentially dangerous animals (8.2.13) can also find the diver reaching into a mouth or a venomous appendage.

In addition to the normal standby diver, it is recommended that there should be instantly available a spare, full breathing set for use in the event of a diver becoming fouled and being in danger of exhausting the air supply before he/she can be removed to safety. Life-lines are useful in quiet water or when an unencumbered ascent can be made. The presence of a shot-line, sampling gear and currents creates the possibility of a life-line snagging. In currents with bad bottom visibility, the divers must descend feet first on the line in the bottom third of the descent. The depth gauge must be monitored during a low visibility ascent to ensure that the safe rate of ascent is not exceeded. Roping to the surface can be used if conditions allow but many scientific dives are carried out where a fixed line to the surface introduces additional hazards. A sharp knife must be carried on low visibility dives, and it should have a sawing tooth upper edge. The knife as well as other hand tools, should be on a lanyard, so that it cannot be lost in the low visibility.

Diver-held lights usually render an unworkable situation workable and the type of light and the question of whether it should be held or mounted on a helmet or a piece of equipment should be left to the personnel involved. Different solutions will undoubtedly suit different divers, projects and conditions. Spot point lights (8.2.9) are useful in low visibility just as they are at night. It is strongly recommended that inexperienced personnel be trained in low visibility conditions in advance. Using a face mask blacked or greyed out using translucent plastic on the trainee will closely approximate working conditions while allowing for close supervision under normal daylight diving conditions.

8.2.18. Confined spaces and vertically restricted environments

Horizontal entry under any obstruction that would preclude immediate, direct ascent to the surface may be made in the course of a scientific dive only with the prior approval of the Diving Officer. Such dives require the use of a diver who remains at the point of entry while the scientist and probably his/her assistant proceed into the opening. The submerged safety diver acts as the link between the vertical ascent to the surface and the horizontal operational dive. Short excursions beneath overhangs are not necessarily to be monitored by this point diver but one of the scientific divers should remain farther back toward an open ascent than the other. In all cases, a safety diver should remain on the surface as he/she may have to come to the aid of all three divers. The surface safety diver must be able to bring additional scuba breathing sets to the divers in the case they must extend their dive and must have extra air. Octopus rigs on single cylinders are recommended rather than one cylinder per diver for emergency air. Compressed air must be available for any possible extension of dive time and decompression. Any dive which involves the use of a second breathing apparatus for a diver must be regarded as an emergency. Long horizontal entries are not recommended and safety must be given priority over scientific objectives. More rigorous standards must be applied to cave and cavern diving (8.2.19).

8.2.19. Cave diving

Diving in underwater caves has, in recent years, developed considerably in both technique and expertise. Underwater caves are entered for reasons of pure exploration and survey, for biological, archaeological and geological research and other scientific studies. Cave diving presents problems not encountered in open water diving, many of which are not necessarily obvious to a first-time cave diver. It is worth noting that several hundred fatalities have occurred in underwater caves in the past decade through the non-use of many of the accepted techniques. Cave diving is an extremely hazardous type of scientific diving owing at least in part to the inability of the untrained diver to perceive and assess the true risks.

Cave diving is a combination of speleology and underwater expertise. Both constituent disciplines affect the equipment and techniques involved.

Before undertaking a diving programme in which cave diving plays a part, contact should be made for specialized training and advice with the relevant national bodies concerned in the home and field nations (e.g. Cave Diving Group in the UK, NSS Cave Diving Section in the USA, etc.).

Because of the inability to surface easily from an underwater cave, any item of equipment whose direct malfunction could cause a fatality (e.g.breathing set, regulator, torch/flashlight) should be duplicated. Octopus regulators are not considered adequate in this respect. A minimum of three torches/flashlights should be carried, each with the burn time of twice the estimated dive time.

The diver must always be in contact with a guideline to the surface. This line should be laid and controlled by the diver, using a hand-held line reel. This shall be of sufficient strength to prevent accident or breakage as the situation demands, and shall be as visible as possible (color may depend on the type of water to be dived).

All vital equipment such as knife, contents gauges, torches, etc. should be worn where they are easily accessible, ideally on the upper torso or arms. No equipment should be allowed to hang free, possibly causing entanglement or visibility-limiting sediment displacement.

The diver must be thoroughly familiar with any technique to be used in an underwater cave beforehand in open water, ideally in both clear and low visibility.

The use of a standby diver may be relevant in certain situations, but unless this diver is more experienced than the one underwater, and entirely familiar with the system in question, use of the standby diver in an emergency could exacerbate the situation.

If a cave is large enough, and personnel are adequately trained and experienced, dual penetrations can be made. Every member of a team must be well briefed in the dangers of the particular environment to be entered.

Sediment is generally present in caves and, once stirred, it may take several hours to settle, as it is usually very fine grained. Cave divers should avoid disturbing sediments wherever possible, by fine use of buoyancy (6.2.15) control and movement, and should be prepared to cope with the psychological effect of physical enclosure in zero visibility (8.2.17).

Currents in marine caves can be exceptionally strong, rising to over 5 knots. These may suddenly reverse in direction as part of a usually complex underground water circulation pattern. Changes in movement in marine caves may not be in phase with surface tides. Equipment and dive planning will take into account such variations in the physical conditions in a cave during the course of a dive.

Pockets of air inside caves may be toxic or may contain no oxygen. Gas may also be present in an explosive mixture. Therefore gas found in enclosed cavities should only be breathed with caution.

Stress is always present in cave diving, in excess of levels experienced in open-water diving. This has been a major contributory cause of fatalities. Divers must make every effort to reduce stress levels before and during a cave dive.

No more than one-third of the total air supply shall be used on the inward dive. A minimum of two-thirds of the air supply shall be conserved for exit and emergency reserve. If decompression is indicated, the reserve 'third' of the air supply should not be regarded as being available for that purpose. Additional scuba systems may be carried and used to extend cave penetration distances or times. As a consequence of long horizontal cave penetrations at moderate depths, cave divers have accumulated a significant experience of safe decompression diving using US Navy Exceptional Exposure Tables (USN Tables, 1986, deep diving/decompression sections).

Deep diving in caves is extremely hazardous, and it should be recognized that in an emergency, evacuation to recompression facilities can be exceptionally difficult from a cave environment.

If more than one diver is present in the cave, then each diver must fulfill the conditions outlined in each paragraph of this section.

Cavern diving is different from cave diving in that while it is also diving in a spatially restricted environment, free emergency ascents can be made. Natural daylight, although possibly dim, is available. Many of the procedures relevant to cave diving will apply.

8.2.20. Noxious gas in bottom water

Noxious gases such as hydrogen sulfide, ammonia and methane commonly occur in anoxic halos to concentrations of fecal matter under fish cages and mussel rafts as well as in areas of sewage settlement. Hydrogen sulfide may be absorbed through the skin and can diffuse into masks through the material. Divers should therefore wear full dry suits and positive pressure helmets (NOAA Manual, 1975). Caution should be exercised in taking specimens of sediments or water where dissolved noxious gases are suspected because when these de-gas at atmospheric pressure potentially significant volumes of explosive gas may be exsolved.

8.2.21. Deep diving on air

This section deals with diving on compressed air at depths deeper than 30 m. Dives in excess of this depth are inherently more dangerous because of the increased possibility of decompression sickness and the greater time that it will take a diver to reach the surface in the event of an emergency. Incidents at depth are simply farther away from surface support. Normally decompression diving should be kept to a minimum in deep diving and where decompression stops are necessary, they should always be carried out with very conservative manipulation of tables. See Section 11 for effects of varying the dive profile.

In most countries the recommended maximum depth for employed divers diving on air is in the region of 50-60 m. Some countries enforce a legal maximum depth on air, which may or may not apply to scientific divers: UK, 50 m or deeper with exemption; France, 60 m; South Africa, 60 m; USA, 58.5 m (190 ft). In the USA the American Academy of Underwater Sciences recommends that divers be certified by progressive experience to depths of 30 ft(9.2m), 60 ft (18.46 m), 100 ft (30.8 m), 130 ft (40 m), 150 ft (46.1 m) and 190 ft (58.5 m). In Canada, the Canadian Association for Underwater Science recommends that divers be certified in progressive depth increments of 10 m with a depth limit at 40 m, unless special deep diving training has been provided. The Woods Hole Oceanographic Institution (USA) and most research organizations in the United States require a limit of 40 m unless special authorization has been granted by the Dive Control Board.

Bounce dives to just shallower than 50 m, not involving decompression may be made, provided that the divers are fully worked up (4.9). Deep diving must be preceded by recent dives of increasing depth to acclimate the diver's body with the greater pressures encountered. A bounce dive, however, is by definition a short dive which does not allow enough time for poorly vascularized tissues to become saturated with a higher concentration of dissolved nitrogen, and therefore these dives should not be more than 5 minutes bottom time. The divers are advised to follow a shot-line and there should be a fully kitted up standby diver with no nitrogen loading. The working divers should be instructed that an emergency situation will be considered to exist if they do not return to the surface within a few minutes of dive plan time. Repeated short dives with short surface intervals should not be carried out.

Bottom time should not be so long as to dictate a decompression time of more than 20 minutes. This time limit should be decreased if conditions are bad, i.e. cold water, heavy swells, strong currents, etc. A planned decompression time of more than 20 minutes involves the dive organizers in complying with stricter regulations concerning on-site compression chambers in some countries. In all cases diving should be carried out so as to avoid extension into the Extreme Exposure Tables.

The support vessel should be capable of transporting divers to the work site in comfort, transporting the dinghy, providing recompression facilities if necessary and carrying shot weights and buoys, ropes and anchors and also have a ship-to-shore radio.

An absolute minimum diving team for deep diving is 4 divers, plus the boatman, standby diver and compression chamber operator if necessary. The standby diver should be fully equipped to dive at the working pressure if necessary. He/she should not have undertaken diving so recently that he/she would be liable to decompression stops after a very short duration at depth as this would make it dangerous for the rescue diver to bring an injured diver to the surface.

Where deep diving is taking place it is always safer to have recompression facilities on the support vessel. These facilities should consist of a compression chamber with lock-in and transfer under pressure facilities and a trained operator whose sole responsibility is maintenance and operation of the chamber. This arrangement is often not feasible. See Section 11, Table 11-3 for proximity to chambers.

The Dive Supervisor, Dive Marshal or Expedition/Project Leader should be thoroughly familiar with the local recompression facilities and informthe appropriate authorities of the diving programme so that they may be more capable of helping should an emergency arise.

Deep diving in remote areas should be carried out using dive plans that keep the divers on the conservative side of the normal decompression tables at all times, unless the support vessel or nearby base is fully equipped to treat decompression cases.

8.2.22. Warm and hot water (sabkha)

A sabkha environment consists of a tropical bay or lagoon where evaporation greatly exceeds freshwater input. Salinity is usually high, and salts may be precipitating. Water temperatures may be over 40oC. Most of the waters of this environment are in shallow water shelves facing arid or hot deserts, and thus the diving is usually in shallow, warm to hot water with weak currents and no dangerous surf. Being close to the surface during diving where an intense sun will be at high angles for most of the day, and being in warmer than normal water, means that the divers have to take precautions to avoid sunburn, sunstroke, dehydration and hyperthermia. Divers can drown even in comfortable shallow water and momentary unconsciousness brought on by the special hazards of the environment can lead to drowning.

Divers are advised to wear a light 't'-shirt and to cover the back of their necks from the direct rays of the sun; waterproof sunburn lotion should also be applied liberally, especially to the backs of the legs and arms because in the normal swimming position, these face upward. Divers should drink copious amounts of water as they will be dehydrating while in the water as the body attempts to cool itself by sweating; a process that will not be noticed by the diver in warm to hot water. Hyperthermia, or ill-effects brought on by sustained high body temperature, must be avoided. Symptoms are general weakness, faintness leading to momentary unconscious- ness and often a faint muscular trembling accompanying light-headedness. If these symptoms are perceived during the course of a dive in this environment, immediate surfacing and inflation of the life jacket must be carried out by the diver.

Because waters are more saline than normal sea water, irritation of the eyes, nose and throat membranes is likely, but unless exposure is prolonged, no immediate or long-term effects are likely. Care should be taken to wash the divers as well as the diving gear with great care following each dive.

8.2.23. Super saline water

The observations and procedures that will be referred to in this subsection draw on the experiences of scientific divers in the Dead Sea. Most extreme cases of super saline water are also in similar environments and less extreme cases that may occur in less arid conditions will have some of the negative attributes common to super saline water. The Dead Sea is situated in an arid zone, where air temperatures in the summer can reach as high as 45°C and in the winter do not drop below 10°C, while the temperature of the upper layers of the sea can be as high as 35°C in the summer while not dropping below 18°C in the winter. The Dead Sea is a basin of net water inflow that acts as an evaporating pan. Salinity can reach as high as 280 g/kg and the corresponding density can be as high as 1230 kg/m3 or about 23% higher than normal sea water. The relative proportions of the chemicals dissolved in the Dead Sea are totally different from their proportions in normal sea water. The Dead Sea waters are rich in calcium, magnesium, potassium and bromine. The high salinity and the dissolved chemicals make the water painful and irritating to the eyes and to the membranes of the nose and throat, so that contact with these organs induces profuse weeping and temporary blindness, breathing is impaired and vomiting may be induced. These waters should not be swallowed, and ingestion of large quantities can be deadly. Moreover, the immersion of open wounds, or even scratches, is extremely painful although not dangerous. In short, for divers, super saline waters are a dangerous, or at least an extremely unpleasant environment.

The high density of super saline water demands the use of about 30 kg of additional weight. These weights cannot be worn on a single belt and must be spread around on several belts to evenly distribute the weight. This makes movement difficult and energy-consuming before a dive and also adds significantly to the time and effort spent in dive preparations. Moreover, by increasing the mass of the diver, the additional weight makes swimming under water more difficult, energy-demanding and air-consuming. The corresponding need for even more compensating weight prohibits the use of under-suit exposure clothing on those occasions when it might otherwise add to the diver's comfort.

The high salinity and peculiar chemical composition of the Dead Sea and presumably similar waters demands absolute prevention of the immersion of the face and this necessitates the use of positive pressure full-face masks. These masks prevent buddy breathing, do not permit mouth inflation of the buoyancy equalizer, are slightly less convenient for pressure equalization, have sufficient buoyancy of their own to cause some discomfort and cannot be transferred from one diver to another without slight adjustments. Slight adjustments to the ABLJ should be made with a direct feed rather than with the more difficult to control emergency air bottle, which should be kept for emergencies. Scuba air supply bottles cannot be replaced during the course of a dive as the face mask, second stage and bottle are a single unit. The full-face masks and their regulators may be mechanically more complex and therefore more prone to failure than a normal mouth-held regulator. In the super saline saturated environment the divers and all equipment require painstaking cleaning and maintenance after each dive.

8.2.24. Lagoons and estuaries

In both lagoons and estuaries, a common hazard is often bad visibility caused by particulate and rotting plant material in the water. The water is commonly colored and lights often cause the water to turn bright red and brown as the light is filtered through the colored water. Even at depths as shallow as 5 m in estuaries on bright, sunny days, the water can become very dark. Total darkness approaching that of a night dive is commonly encountered in these environments below 10 m and although lights maysomewhat alleviate the problem of visibility, they will not have the effect that they have on a night dive in clear water.

Currents in lagoons are usually slack, and the water is often stratified in both salinity and temperature. In estuaries, however, currents are commonly strong, especially in the race or bore of the river. Fast water diving methods (8.2.8) should usually be used when diving in estuaries. In the case of a shore dive in the channel of an estuary, the dive plan should leave time for a submerged return to shore as upon surfacing the divers will usually find themselves caught in faster moving water than they were encountering on the bottom. If they cannot resubmerge to more slowly moving water near the bottom without incurring a decompression situation, they may find themselves swept along rapidly in the river far from where they put in or in the worst case, out to sea. Under no circumstances should the divers in this situation submerge and begin a repetitive, hard working decompression dive when they are likely to exhaust their air swimming against current.

8.2.25. Holiday Environments

Scientific diving is commonly done in out of the way places where interference by local people or holiday-makers with diving operations is usually not a problem. Some scientific diving sites, however, involve working from shore areas in which there are people ranging in numbers from a few interested locals to swarming crowds of holiday-makers. Fishing boat traffic and water sports must be taken into consideration as well as shore constraints in dive planning.

Apart from the normal 'hazards' of holiday environments, such as late nights and incautious entertainment, diving in areas where large numbers of families are on holiday introduces some special conditions. Divers must remember that their operations are disturbing the local environment. Extra hazards to divers occur as diving sites are often within sight of large numbers of people with little to do; increased boat traffic over the dive site and actual visiting of the site by other divers can both slow down the work and be very irritating especially if divers are fatigued. Normal conduct of operations often becomes difficult and extra time should usually be built into operational plans for dealing with non-party members; it is very important for good relations to be maintained with locals and holiday-makers, however, and remaining polite is important. Although it may not be a legal requirement, it is often a good idea to notify the local police or the local water police about dive operations.

Security of diving equipment and samples can be a real problem if public facilities are being used for water access. Although most people are quite honest and not liable to steal equipment, swarms of children may get in the way and have a tendency to pick things up out of curiosity. It is advisable to have all gear, especially the many small items, in bags or boxes so that few opportunities are presented to the curious or the malicious. Theft of diving equipment after the dive, usually when it is drying after post-dive washing, is a common problem.

8.2.26. Whirlpools

'Whirlpool' is a common name given to rotating turbulent water masses that are one of the high energy environments in which diving is usually avoided for reasons of safety, but in which interesting physical and biological processes take place.

Freshwater waterfalls, with turbulent water and whirlpools are associated with a number of interesting processes relating to rock erosion and solution, biological processes in the pool below the waterfall, and fish migration up the waterfall. In narrow sea channels, around some headlands, or at the entrance to sea lochs or fjords when tide is running, eddies and whirlpools commonly occur. The rotating water mass, or whirlpool, can be differentiated from a common eddy because in a whirlpool the water tends to make many circuits and rotate rapidly enough to create a force upon bodies caught up, and force them to the outside of the gyre, as well as often pulling them down.

Very little scientific diving has been done in this environment, but work which has been achieved suggests that conditions for diving in whirlpools are not prohibitive, provided that common sense precautions are carefully observed. The obvious risks arise from the diver being thrown against rock outcrops, against the bottom, or getting tangled in ropes or moorings and dragged downward by the lateral drag on their body. Similarly, the surface cover boat may be in considerable danger, and the boat and diver may be easily separated. While the speed of motion and turbulence may be disorienting, they are not dangerous, provided that the diver does not collide with any solid object.

Diving strategy, therefore, is to leave the boat or shore in calm water, enter the turbulent water as unencumbered as possible, move freely with the rapidly moving water, and then exit into calm water for recovery, possibly by a second boat. Such manoeuvers should only be attempted by experienced divers, with very good back-up and surface support.

The downwelling plume of turbulence from a small waterfall of a few meters head can be approached safely underwater, or on the surface, with care. If the diver ventures into the most turbulent zone he/she is immediately swept downstream and out of danger. With larger waterfalls the impact of falling water and objects such as trees carried by the water, would be extremely dangerous. There are no records of divers attempting to approach the plume of a large waterfall from below, or to work in this environment, although some projects have been suggested. The greatest danger would exist if there are any currents or gyres, which drag the surface water into the immediate fall zone of the waterfall. This is quite likely, and any waterfall pool should be studied very carefully and tested with floating objects the size of a human body, before any diver enters the pool. Any work of this kind must be treated as highly experimental, and divers must be advised to use every possible safety precaution and back-up.

Canadian divers have developed very effective techniques for working in white water conditions of rapids, rock pools and small waterfalls. These techniques could probably be extended to cope with the situation of larger waterfall pools.

8.2.27. Underwater volcanoes and igneous intrusions

Diving in the vicinity of volcanic activity can only be described as extremely hazardous. Obvious dangers include explosive gases, excessively hot water and high turbidity. The only case where scuba divers have directly observed underwater lava flows is Hawaii where in 1970-1973 a number of lava flows entered the sea from a subaerial eruption from the flank of Kilauea Volcano (the Maunaulu vent) on the island of Hawaii (Moore et al., 1973). Because these flows originated subaerially, the lavas had several days' time to de-gas before entering the sea, and they were not nearly as explosive as they would have been in the case of an underwater eruption. Underwater eruption is prohibitively dangerous and is never recommended for diving except in the case of hydrothermal vent activity, which normally is limited to gaseous emissions (black smokers). Actual eruptions underwater are probably best analyzed by remote instrumentation.

In the case of subaerial eruptions which enter the sea, the most dangerous factors to consider are heated water, turbidity and gaseous explosions. Heated water accumulates at the sea surface owing to its low density. The thickness of a heated surface layer will be a function of the amount of lava entering the sea and the degree of mixing at the shoreline. Longshore currents may greatly aid in the dispersal of heated water. Divers should avoid heated surface waters. This can be done by entering the sea outside the area of influence and swimming under the heated plume to active sites (Moore et al., 1973; Grigg, 1973). On steep slopes divers should be aware and cautious of avalanching rock and gaseous explosions. This can be done by swimming several meters above the bottom. Observations of such volcanic flows can only be made under conditions where small amounts of lava enter the sea. Decisions concerning the safety of such missions must be made on-site. Another factor to consider is turbidity. Directly over underwater lava flows the water is often extremely turbid, too turbid in fact to operate safely. To avoid areas of high turbidity, divers should operate on the upstream side of active lava flows or possibly at slightly deeper depths. A third factor to avoid is operating surface vessels which have seawater cooled engines in areas of heated plume water. Engines exposed to such conditions may overheat to the point of on-site failure. Divers should wear protective wet or dry suits, which serve as insulation to the heat as well as acting as protection from sharp, freshly fractured lava surfaces.

Divers operating in submersibles at hydrothermal vent sites might also take into consideration these suggestions to divers. The degree to which caution must be taken will depend on local conditions and the nature of the submersible, which can best be judged by on-site observers and divers.

8.2.28. Hot springs (potentially dangerous hot water)

Excessively high temperatures are rarely encountered in diving (8.2.22; 8.2.23). Hydrothermal springs or hot water vents can nevertheless be foundin volcanic areas. Although emitted heat can be very high, it is generally concentrated in a few spots and rapidly dissipates into the surrounding water. Only in closed, small basins with limited water exchange can temperature rise to dangerous levels, while in lakes and the sea, even very close to the vents, temperatures suddenly drop to values of the normal environment. With water vents, gas is often present. Sometimes it rises as bubbles or pressure-driven bubble streams at elevated temperatures. Depending on the amount of gas and the depth, it may form a column rising toward the surface before it dissipates and can be dissolved.

Owing to differences in density, waters of different temperatures are usually easily seen because of the induced clear water turbidity marked by 'trembling' light, but when the vents carry chemicals in solution or in suspensions, they are smoke vents.

A normal diving suit is usually sufficient protection against hot water, that nevertheless must be approached with care. Real danger of scalding is a very rare situation. Long exposure to warm water can nevertheless cause hyperthermia of divers with consequent dizziness, headaches and difficulty in breathing, which can lead to unconsciousness and collapse of a diver. Usually a rest in a cooler place will promote a rapid recovery from incipient hyperthermia, and medical assistance is seldom needed. When one has to dive in warm water or near hot springs, physical exercise should be kept to the practical minimum.

8.3. Artificial, experimental and unusual situations

Diving is increasingly being carried out in situations that range from the commercial scientific (fish tanks, shellfish rafts, etc.) to the scientifically bizarre (e.g. studying algae growth in nuclear reactor cooling tanks). Although some of the subsections here will not apply widely through the diving community, the recommended procedures are derived very largely from the experience of the technically developed countries and will have increasing application in developing countries.

8.3.1. Fish tanks, cages, farms, shellfish, rafts, diving in enclosures and other containers

Large containers are being used with ever increasing frequency by scientists and fish farmers. While diving procedures in large dammed impoundments and land-based tanks should take account of the special recommendations for confined spaces (8.2.18), culverts (8.3.3) and inside storage tanks, many enclosures are deployed in open water and require somewhat different practices. This section deals specifically with diving in and around floating enclosures.

Types of enclosure: Floating enclosures are usually made in three types of material, impermeable sheet plastic (e.g. polythene, PVC), closely woven material (e.g. plankton net, sailcloth) and fishing net. Usually the sheet plastic and closely woven material are used for scientific experiments while fishing net is predominantly used for the manufacture of sea cages in aquaculture. Ideally the plastic and closely woven enclosures will be relatively rigid fixed volume systems while the net bags are usually loosely constructed.

The basic design of each system is similar, comprising a flotation collar, a container supported by the collar and a mooring system. The flotation varies according to the design but in the larger systems it usually doubles as a service platform. In this case it will be substantial and reasonably stable. Moorings can be independent but frequently several enclosure systems are interlinked by chain or rope to a common anchor.

Diving procedures: Diving on enclosures is usually associated with deployment, maintenance and dismantling. The particular dangers are entanglement and being trapped between adjacent systems. <u>A sharp knife with a saw-tooth edge must be carried</u>. If convenient the knife should be worn on the forearm or the inside leg. Since enclosure systems are large and often complex pieces of apparatus, it is advisable for divers who are unfamiliar with the system to dive initially with someone who is familiar with it, or failing this, to be briefed fully on the layout and design before entering the water. Since most enclosures are supported from the surface, the diver often has to approach the equipment from below. The diver should be aware that the escape route in an emergency frequently could be to descend before making for the surface.

Diving around enclosures:

Underwater. The biggest risk while underwater is becoming tangled in the ropes and associated equipment. Netting, especially larger mesh material, can be exceptionally dangerous, particularly when unsupported or otherwise loose. When handling netting underwater extreme care should be taken and the diver should always attempt to face the netting in order to minimize the chance of the material being caught around the demand valve clamp. This is probably the most vulnerable part of the diving equipment and is most inaccessible to the entangled diver. The low pressure hoses of twin hose demand valves can be crimped and the diver's air supply cut off by tangled netting or rope. Single hose valves are not so vulnerable. Where possible it is advisable for one of the team of divers underwater to stand off from the apparatus in order to be readily available to disentangle the buddy diver. Strong scissors could also be carried since they will probably be more effective than a knife for cutting slack netting.

Photo 9: Diver working on the supporting wires around the plastic walls of a fish farming cage. *Photo: Crown Copyright. Aberdeen Marine Laboratory*

The base of the enclosures often has heavy weights, which serve to tension ropes, etc. The locations of these should be known and care should be taken to avoid cutting them free accidentally. When swimming beneath the entire system the diver should make sure that there is plenty of clearance. Ropes held taut by such weights make useful hand holds for the diver and can be used in controlled ascents and descents.

With shifting wind, current and often large numbers of fish in net cages, irregular movement of the cage net and the shadow it casts underwater can be disorienting to the divers. Care must be taken to have an external reference, even if it is only a compass bearing.

At surface. It is often necessary to use diving equipment at the surface when servicing enclosures. These structures are most vulnerable to wave action particularly at the point where flexible material is attached to a rigid framework. Before diving, account must be made of sea state, and, where several units are linked, care must be taken to avoid getting trapped between the floating support structures. In some cases a surface attendant should stand by to prevent the units coming too close together.

Diving within enclosures: Diving within enclosures is usually associated with repairs or recovery of dropped equipment. Where possible the practice should be avoided since it can cause claustrophobic feelings and can be deleterious to the experiment. It is inadvisable to dive in systems narrower than 2 m in diameter.

It is usually impracticable to dive in pairs within an enclosure, so a fully-kitted standby diver should be in immediate readiness to dive if required. In an emergency it is most likely that the diver will be freed from the enclosure by cutting the material and escaping through the wall. Even in a normal situation the diver will need assistance to climb out from within an enclosure.

Normal lone diver practices must be adhered to. In addition to the diver's own safety-line or, more preferably, communications cable, whichshould be held taut by the surface attendant, a weighted shot-line down the center of the enclosure tied to the support framework is a useful reference point and provides a means of effortless vertical movement for the diver. It is frequently difficult and often undesirable to fin actively when inside an enclosure.

It is possible to repair punctures in watertight enclosures by clamping the damaged sections between suitably sized rigid plates or strips of wood. This requires divers both inside and outside the enclosure simultaneously. Although the material is usually translucent to some degree, it is often difficult for the divers to locate each other on either side of the wall. The best procedure is for the two divers who are to make the repair to arrange to rendezvous at some point on the surface and then to descend together to the damaged area keeping contact by touch through the flexible wall of the enclosure. The buddy diver for the 'outside' diver should stand off and watch the procedure.

When watertight enclosures are damaged they usually collapse. This can create difficulties for anyone diving inside since the airlift effect of the exhaust bubbles tends to draw material around the diver. It is important to be aware of such a possibility since the collapse tends to happen without warning, particularly when the diver is working at the base of the system. It is difficult to swim in such a situation but easy to escape either by hand hauling up the shot-line or by careful use of a buoyancy aid such as an ABLJ or inflatable dry suit. In an extreme situation, the diver should be prepared to make an emergency escape through the enclosure wall by cutting through it.

There are no texts specifically on the methodology of enclosure techniques for scientific purposes. The introductory chapter in Grice and Reeve (1982) illustrates some of the types of floating enclosures used. Although there are many books on aquaculture, there are as yet no suitable descriptions of the types of sea cages used in the industry. New designs are constantly being developed, which further emphasizes the need for the diver to be familiar with the particular system before entering the water.

8.3.2. Support, launch and recovery of gear

The supporting role of the diver has proved invaluable time and time again to the marine scientific community. The majority of equipment used in marine research is complex and expensive and often the safe deployment and recovery can be aided by divers.

It is assumed that the equipment is either bulky, heavy or both. Diving techniques may need to be worked out to overcome the problems involved in being on or near heavy or awkward gear moving relative to a ship. A good dive boat should be used (9.2), and the mother ship must have a smaller boat ready for immediate launch in case of emergency.

All straps, shackles and lifting gear must carry the relevant in-date test certificates pertaining to the legislation of the particular country or countries involved. Prior to the start of a dive, arrangements should be made to ensure that no sewage or rubbish is dumped over the side for the duration of the launch or recovery. Apart from the obvious discomfort for the divers, it can also attract unwanted visitors such as sharks.

There is a possibility that a diver may drift away from the ship; this may be caused by the way on the ship or currents and wind. Divers should carry emergency flares and a dye pack. A whistle is a good idea for short distances. When night work is involved the diver should carry a flashing light.

There is little difference in diving technique when handling heavy gear, and most of the concern is brought about by being on or near equipment weighing 2 to 20 tonnes moving relative to the ship. This type of equipment may either be a towed body, a submersible, something that is lowered to the sea bed or a buoy or float. These may be launched either from the side or the stern of the vessel. Some of the following apply to one situation only:

1. Straps and lifting gear may have to be tested under mandatory regulations.

2. The launch should take place on the windward side of the vessel so that the vessel drifts away from the equipment.

3. Fenders should be large enough to allow a 0.6 m gap between the equipment and the ship under maximum compression, so that in the event of a diver getting between the two, room will remain. These fenders should be attached to the equipment so that in a swell they move with the equipment, are not forced out and will not roll along the ship's side.

4. Two lines should be rigged fore and aft on the equipment to a towing point on the support boat which should tow off stern first in order that the coxswain can see what is happening and may apply full power to one tow line or the other if necessary.

5. If it is possible, release of lifting gear should be by remote means. If this is not possible, then the hooks should be fitted with grab lines, and the divers should wear protective helmets.

6. Care should be taken that no diver is caught beneath a pitching stern, particularly if the ship is transom sterned. In vessels with spoon counters it has been found that divers are displaced with the water, although this should not be relied upon.

7. In stern launch procedures, it is general practice to have way on the parent vessel. As this requires the use of the propeller, close contact must be maintained between the bridge and the diver's boat. When the propeller is started or revs increased, there may be a large surge and this is potentially dangerous.

8.3.3. **Locks, culverts, ships' propellers or hydraulic inlets**

There is absolute necessity in diving around heavy machinery or hydraulic intakes for the diveer to ensure that nothing will be moved, started or operated while the diver is in the water other than carefully planned and executed test procedures. All automatic operating systems must be disabled and the engineer, ship's captain or the person otherwise incharge of the operation of these systems must work closely with the diver and his/her handlers. It is strongly advised that the diver and the surface handler be in constant communication both for the efficient carrying out of the tests or inspections and for the safety of the diver. The danger of a diver being sucked onto the grill over a hydraulic inlet must be avoided. Procedures for locking the propeller shaft, etc. are laid down in Navy manuals and commercial diving manuals.

8.3.4. Diving underway

For the purposes of this section, the term 'underway' shall apply to ships moving through the water. Also see Section 8.3.5.

A vessel will require a diver-support boat under these circumstances:

1. If it is of such a size that it cannot approach divers safely in prevailing weather conditions.

2. If it is of low manoeuvrability whether inherently or as a result of apparatus deployed from the ship.

3. If a diver's body heat will be lost rapidly when he would otherwise be towed through the water.

4. If delays in recovery of the divers are possible.

Separation procedures: Where appropriate the divers shall carry flares, fluorescent dye packs, a strobe light and a whistle. If the risk of a diver being separated from the support boat is thought to be great, radio beacons should be worn or fixed to a surface buoy on a shot-line. Consideration should be given to the use of acoustic communications or pinger and tracking devices. There may be circumstances, for example working on fishing gear, when it is safer to reduce extraneous gear to a minimum in order to reduce the chances of becoming snagged on the moving apparatus.

If a diver is seen to be drifting astern and the support boat is unable to pick him/her up, a previously prepared buoy shall be dropped to mark his/her position. The diver should make every effort to attach himself/ herself to the buoy, which will be fully fitted with rescue equipment. The buoy should be large enough to be found and should have a radar reflector.

When working on towed apparatus, there should be a trailing-line leading to a substantial surface float. This can be fitted with one or more quick release clips so that divers leaving the apparatus are marked at the surface. If one diver has reason to surface, he/she should ascend the trailing-line. The surface support boat should be stationed alongside the trailing-line float.

If it is noticed that a diver is missing, the marker buoy should be dropped immediately to provide a reference point.

If a diver drifts astern unnoticed, first the whistle and then up to half the flares should be used. It is important that the diver's flares are acknowledged as soon as they are seen in order to prevent panic. If these are not acknowledged, the diver should proceed in the direction of the shipassuming that no reference buoy has been dropped. If there is doubt as to the direction of the ship, the diver should remain where he/she is; after swimming in the direction of the ship for about half an hour and finding no buoy, the diver should stop to conserve energy.

The fluorescent dye pack should be securely attached to the diver and should only be used if an aircraft is sighted in daylight.

Decompression: Decompression diving underway must be avoided.

8.3.5. Diving on towed fishing nets

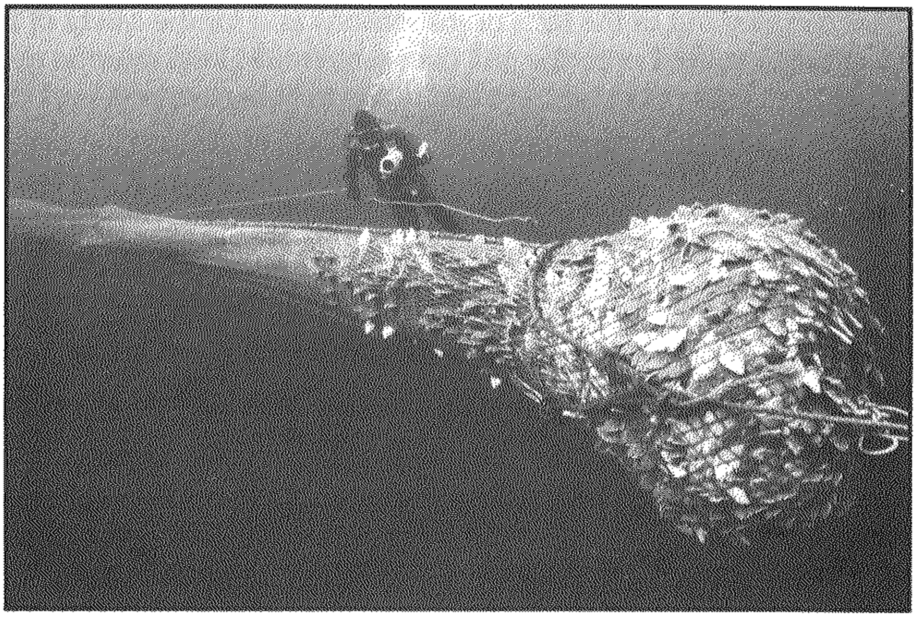


Photo 10: A scientific diver moves over the trawl observing the fish, and photographing the net's performance. *Photo: Marine Laboratory, Aberdeen*

Diving on fishing nets is a practice that has developed over the years by research scientists involved in the design and engineering of trawling gear and in the behaviour of fish reacting to the gear (Main and Sangster, 1976, 1978, 1981, 1982, 1983, 1984, 1985). It is not a dangerous type of diving, if approached with both common sense and good diving techniques. However, it is different from almost all other standard types of diving, as the fishing net or fish species under study is always in motion. Therefore the diver has, on most occasions, to keep up with the subject while being towed through the water at speeds up to a maximum of 2 m per second (4 knots) and obtain results.

Direct observation and quantitative measurements by divers on trawl fishing gear require the development of a great deal of personal skill and experience and must be approached with caution. Initially, a great deal of time is needed to develop both skill and the methods that will produce the maximum amount of relevant information during each dive in a limited 'no-decompression' time.

Choice of diving personnel: Divers should be experienced and well qualified in all standard diving techniques. Divers must be capable of maintaining an increased breathing rate and preferably be strong in the arms to hang onto fast moving gear and withstand an increased body drag. The divers should not be prone to seasickness, as vessels can work well offshore.

Basic training: Although the ideal approach is to work with a team already well versed in fishing gear diving, this may not be possible for various reasons. The alternative is to try to simulate the real thing. A simple approach is to tow a heavy weighted rope behind a boat at a relatively low speed (1 knot). Allow a selected pair of divers to descend to the weight at approximately 10 m depth, hang on and attempt simple tasks while trying to regulate their breathing rate at that towing speed. Increase the speed and complexity of the tasks, as experience permits, e.g. photography or communications. Instruct the divers to move their heads into and across the water flow, to feel the effect of drag on the face mask and mouthpiece. All these simple steps will improve their ability for underwater work and increase their strength at realistic towing speeds.

Equipment and accessories: This type of diving requires a lot of common sense. Always remember this when choosing your equipment prior to adive. Nets are full of snags and diving equipment has many pins, buckles, toggles, etc. Only take equipment that is really necessary for the job in hand. The most suitable diving gear is:

1. Dry suit with suit inflation worn over an appropriate undersuit. This will provide adequate insulation in cold water conditions.

2. Single tank scuba with a quick release harness. It is preferred to a twin set or a back-pack because it is lighter to handle on the heaving deck of a ship and is less of a drag on the individual at higher towing speeds.

3. Single hose regulator fitted with a contents gauge rather than the twin hose demand valves. It has been known for the second stage to purge due to the water flow, but this is not a common occurrence and can be overcome by a small piece of easily removable tape or by fitting a stronger spring. If taped voice recordings or communications are necessary on a dive, then a mouth box can be fitted to the second stage in place of the mouthpiece. This is preferred to the full-face mask although either will reduce the pressure on the jaw muscles and will also keep the lower face warm and protected against jellyfish stings.

4. A depth gauge, watch and knife are essential. The knife should be worn on the forearm rather than on the thigh or lower leg. In this position it is less prone to snagging and it is more accessible in a current which tends to straighten the body.

5. A small cassette tape recorder in a watertight housing with a remote microphone on a 'flying lead' allows many minutes of continuous real- time information to be stored. This system eliminates the use of writing, etc. A diver-carried, self-contained, low-light video-recording system with an audio track is probably the ultimate in free diving efficiency.

6. A large inflatable boat with a powerful engine is recommended. This rescue/tender boat should have a diving ladder for easy access, VHF radio for communication with the towing vessel and all necessary safety equipment.

Pre-dive procedures at sea:

1. A total understanding of the geometry of the gear by the divers and a pre-dive briefing with skipper, crew, divers and boatman is essential so that everyone understands what is expected of each person.

2. A team of five divers is ideal, preferably diving in pairs with a maximum of three diving at any one time depending on the task. Two divers is the most practical team, with the third used as a standby diver in the tender boat.

3. The skipper of the fishing vessel should inform other vessels in the area of the proposed diving program and ask them to stay clear. The 'A' flag must be shown.

4. Operations will almost certainly be dictated by weather conditions and it is usually the tender boat being unable to cope with the sea state that will cause cancellation of the exercise.

5. Although the expected diving depth has been pre-planned, unexpected changes in depth due to surface wind changes and cross tides can alter the ship's course into deeper water. Be aware of the depth that must not be exceeded and carry decompression tables for emergency use.

6. The tender boatman will be in a position behind the towing vessel. It is often impossible to follow air bubbles unless there is a calm sea; therefore, the boatman should look astern of his craft as well as to the sides and ahead. It is beneficial to have a lookout with a radio situated on the stern of the towing vessel as that person is higher above the water and can see farther.

Free diving on towed fishing nets: There are basically three types of moving fishing gear: seine net, pelagic or mid-water trawls and demersal or bottom trawl.

1. **Seine net.** This is the easiest type of gear to work with, as the net begins from a stationary position and slowly increases in speed through the water up to about two and a half knots. The danger point, in this category of net, is the fact that the netting is quite loose and floppy in the stationary mode. The meshes can easily snag a diver, but as the net moves forward, it becomes quite firm and safe to hold on to.

2. **Pelagic net.** This can be the most dangerous type of net to the diver because it can be towed over very deep water. The net can also drop through the water column for a number of reasons. If a diver were caught up in a trawl and the buddy-diver could not release him/her, the ship could not be stopped and the net would have to be winched up to the surface at a speed that the diver could endure.

3. **Bottom trawl** (see Figure 8-2). This is safer than other gear to dive on, as it is towed over the bottom and in the event of any mishap, the ship can be stopped without fear of the net sinking into deeper water. There are problems of sand and mud being thrown up by the otterboards and passing back along both sides of the trawl, often completely obliterating part of the wires and netting. Until experience is gained, it is essential that the vessel tow a straight course to minimize this danger.

Observing technique: The divers begin either from the stern of the towing vessel or the tender boat positioned alongside the vessel. Jumping from the stern of the fishing vessel appears to be more dangerous than it really is. A diver entering the water from a large boat is more relaxed than kitting up in a small tender boat. Prior to entering the water, the dry suit must be really well vented of air and the weight belt should be slightly heavier than normal. The team should enter the water and swim down the chosen warp while remaining together. It is not advisable to hang on to the warps as they are greasy and may have broken strands of wire. The divers should be able to follow the warp to the sea bed by treading water and dropping through the water column. This allows time to regulate breathing, check that all divers are in the right frame of mind for the task in hand and adjust cameras, instruments, etc. The divers swim past the otterboards, sweeps and bridles until the net approaches and both divers can then either catch hold of the net and be towed through the water, or alternatively allow the whole net to pass by. The latter method is used really only for filming techniques. Never attempt to swim with the fishing gear as the diver cannot sustain fast speeds for any length of time. On completion of the exercise, return to the net and stay together, leavetogether and do not waste time on the sea bed. Check depth and time and ascend to the awaiting tender boat. On the surface stay close together. Never use blob-lines or marker floats as these can be lethal when working with fishing gear (6.2.7).

Towed underwater vehicles: To overcome the many problems of divers hanging onto towed nets, the use of a towed wet vehicle carrying two divers, cameras, communications equipment, etc. is extremely valuable and much safer than the divers remaining free in the water. However, this can be expensive and may need a bigger team to operate it. Nevertheless, this system can produce remarkable results in a relatively short time.

8.3.6. Diving from large ships

For the purposes of this subsection, a large ship will be a vessel of 1000 tons or over, with a freeboard of 5 m or more (8.2.4).

The advantages of diving with a large support ship of this size are the ability to work anywhere in the world's oceans, long endurance at sea, good living conditions, excellent technical back-up, medical facilities, good radio communications, accurate navigation, good laboratory conditions and the possibility of evacuating an injured diver by helicopter. There is also good long-range visibility from the bridge, use of radar and an ability to ride out storms. The opportunity to dive in these circumstances will usually arise from participation in an oceanographic cruise on a large research ship, or possibly research in association with the offshore oil industry or fishing industry or from a naval vessel.

Problems arise from the following factors: high freeboard; difficulty and time needed to launch and recover boats; slow manoeuvrability of a large ship; technical difficulty of starting and stopping main engines; difficulty of bringing a large ship close to shore, rocks or reefs; and danger of being hit by the ship, especially when working near the stern.

High freeboard: Boats, equipment and divers have to be lowered into the water; often from upper decks where there is more space. If a work boat is used, this may be stowed on davits. An inflatable will usually have to be lowered from a crane, using strops. The launch should be on the lee side of the ship. In windy conditions an inflatable can swing or rotate and hit against the hull, unless stabilized with line fore and aft. Divers and equipment may be embarked from a companionway or by the crane. Because of the high freeboard, assistance to a diver in trouble can only be given by people already in the diver tender boats.

Launch and recovery of boats: Launch and retrieval of boats is time-consuming. In an emergency, an extra boat cannot be launched quickly, and similarly, in an emergency, a boat carrying an injured diver cannot be retrieved quickly. Allowance should be made for these factors when planning operations and planning the equipment carried on boats. Thus all boats should be equipped with a radio to the mother ship, radar reflectors, tool kits, first-aid kits, etc. (6.2.5). If the work is in the open ocean, boats should carry complete survival kits and rations.

Manoeuvrability: Large ships have a large turning radius and in addition at slow speeds tend to be influenced by wind. A large ship always has considerable momentum. In the absence of lateral thrusters, a large ship at slow speed or hove to will be strongly influenced by wind. As a result of these factors it usually is not possible or desirable to maintain the vessel in close station to the divers, unless the work permits the divers to drift with the ship. Operations should be planned so that the diving is controlled from the small boats and oriented directly to the boats. The ship may be stationed or drift 1-2 km from the divers.

If the main support ship is needed to launch scientific equipment in conjunction with diving support, it is presumed that the ship will be at anchor, or will have thrusters or dynamic positioning, so that it can maintain station. If dynamic systems are being used, the strictest precautions <u>must</u> be discussed fully with the Ship's Master and the Chief Engineer before diving commences as these initiate automatically and might engage when a diver is in a dangerous position (Appendix 2 for industrial manuals and regulations).

Starting and stopping engines: Large engines must be allowed to heat up and cool gradually. For each ship and engine type there is a strict procedure for the rates at which speed can be increased or decreased. Diesel electric propulsion is an exception since the electric motors can be varied in speed without harming the diesel engines. Similarly, feathering

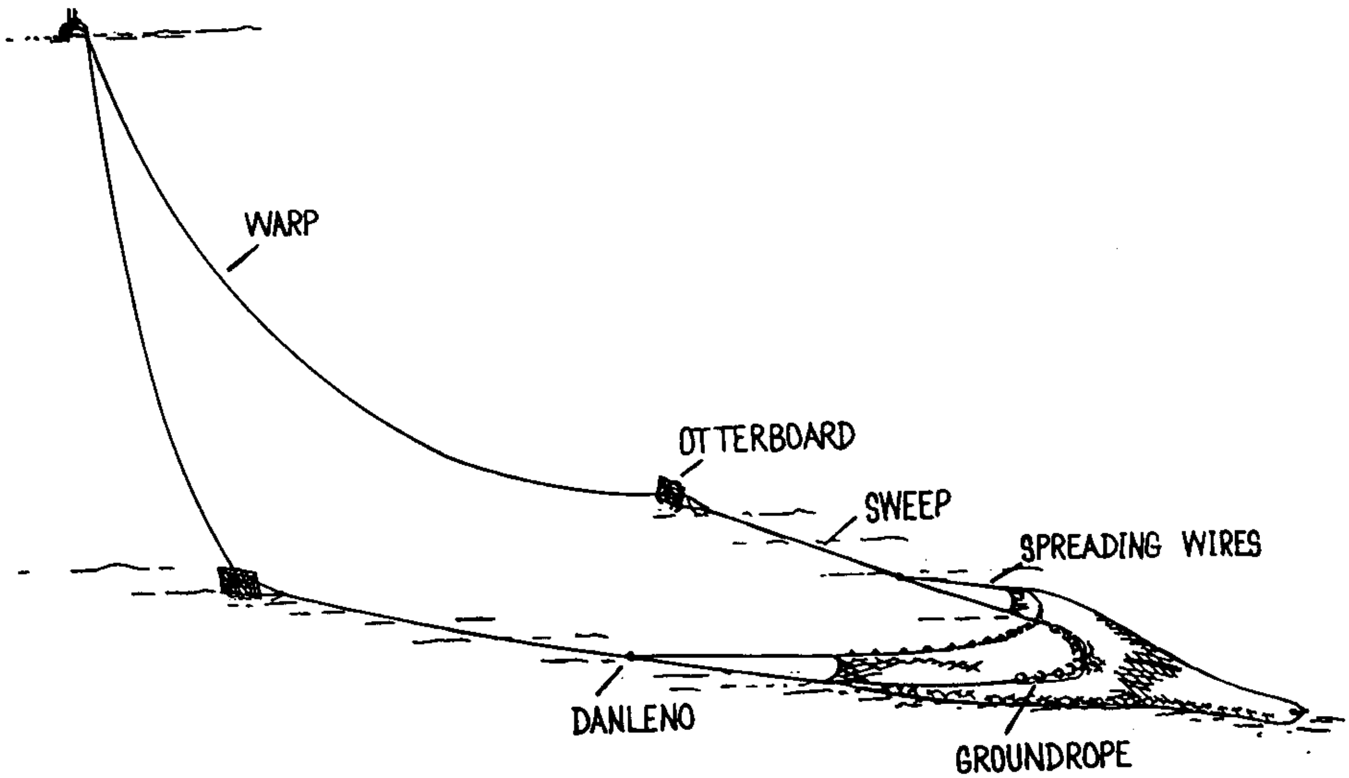


Figure 8-2. Terminology of parts of a trawl net, showing the components which may have to be photographed or measured by divers.

propellers provide added flexibility. Notwithstanding these factors, it is generally true that large ships which are hove to cannot move quickly ahead without advance warning to the engine room. Conversely, the engine room requires notice of intention to stop. By careful discussion with the Ship's Master and First Engineer, it is possible to establish what procedures can be accepted as the norm and what can be done in an emergency, and hence work out a routine for maintaining the optimum close support of the diving operation.

Working close to shore and rocks: The Master of a large ship will not wish to endanger his vessel by bringing it close to shore, reefs or rocks, where quick manoeuvres and rapid changes of speed are essential. It is reasonable for a vessel without thrusters to be kept at least 1-2 km from any navigational hazard. Divers planning geological sampling or study of biological substrate should be aware of this stand-off distance when planning operations.

Working close to the ship: When working close to a large ship, there are dangers from being trapped between the hull and any adjacent boat or equipment, from engine water intakes and outflows, from swinging blocks or lifting tackle and above all from the rise and fall of the stern of the vessel. Depending upon the weather conditions and the precise shape of the stern, the degree of 'slap' will vary from ship to ship. Nevertheless, until close experience and inspection have proved otherwise, no diving should be permitted close to the stern of a large vessel. In all operations close to the ship, there must be the closest consultation between the Diving Officer or Dive Marshal and the Ship's Master and First Engineer. Where relevant, crane operators and other technical support crews should be fully briefed also.

8.3.7. Severely contaminated water, toxic and non-aqueous liquids

Engineering and scientific projects sometimes require working with large quantities of polluted or toxic water, or with non-aqueous fluids such as diesel oil or paint, or in water with dissolved toxic gases. During installation of instruments or sensors, or in carrying out unexpected maintenance requirements, it may be useful to have carefully prepared divers to work in these unusual circumstances. Such circumstances may arise in studying pollution or leakage from dumped toxic wastes, or within large tanks or containers. The strictest safety precautions must be applied in all such circumstances, and the Diving Officer should conduct careful consultations with experts familiar with the hazardous or toxic chemicals involved.

Never dive in fluids containing highly toxic chemicals such as acetic anhydride, bromine, methyl parathion, acrylonitrile, epichlorohydrin, or chlordane. Never dive in fluids that contain contaminants that could dissolve the latex rubber in diving suits. Always consult an expert chemist or pharmacologist to assess the risks from the known concentrations of potentially toxic chemicals in the water before diving.

Foam Neoprene suits are almost impossible to decontaminate after severe exposure and do not provide sufficient protection underwater. A complete dry suit should be used, with integral boots, and gloves that can be sealed onto the suit at the wrists. Helmets must totally enclose the head and be sealed to the suit, and the helmet should preferably have a slight excess internal pressure. Exhaust valves should have a double exhaust flap system so that droplets of fluid cannot leak back onto the breathing circuit.

Suit materials must be smooth and slick on the outside so that they can be decontaminated. The surface attendants and line tenders should be protected by appropriate suits and gloves, since the handling of lines and the diver's equipment will inevitably put them at risk. Before diving, the Diving Officer must ensure that the appropriate decontaminating and scrubbing agents are available on-site so that equipment can be cleaned when the diver exits the water.

Advanced equipment for protection of divers from severely polluted or toxic conditions has been developed by the National Oceanic and Atmospheric Administration (NOAA) in the USA (Barsky, 1986; Tejada, 1985; Wells, 1984).

8.3.8. Sewage contaminated water

Typical situations that necessitate diving in sewage are: sewage works maintenance, sewage outfall construction and maintenance, sewage outfall environmental impact survey and marine engineering site investigation. The main problems encountered are poor visibility and risk to health through bacterial or viral infection. To minimize these problems, first determine whether the sewage flow or volume can be reduced by the operators. Second, carry out the following precautions: minimize exposure of skin to water by using a complete dive suit; use a full face mask; a dry suit is preferable; if a wet suit is used, swim through clean water before and after sewage contamination; use life-lines and diver telephones to maintain contact; have a typhoid and any other prophylactic injections as indicated by local conditions at least one week before the diving; avoid stirring up sediment on the bottom by careful buoyancy adjustment; do not dive with cuts or abrasions; avoid swallowing; wash all equipment and body in disinfectant following the dive; rinse eyes with optrex or some other solution after the dive; rinse ears with earwash solution of 80% iso-propyl alcohol, 5% glacial acetic acid and 15% water after the dive; and spit out saliva frequently after the dive.

If the sewage is untreated (that is raw or only macerated) it is essential to wear a dry suit providing full body cover (8.3.7).

When diving in enclosed vessels such as sludge digesters, roping and voice communication is necessary. Supplied air should be breathed until well clear of the vessel, and the diver should be fully separated from the diving medium. If there is space above the fluid in the vessel, it will almost certainly not be breathable and may be an explosive mixture.

8.3.9. Polluted water and estuarine conditions

Scientists are increasingly required to dive in polluted littoral zones in order to study the impact of pollution caused by biological, agricultural and industrial effluents and discharges. In addition to modern pollution of these waters, many estuaries contain areas that are 'polluted' through the natural processes accompanying restricted water circulation and oxygen depletion. In heavily polluted waters all the procedures associated with diving in sewage contaminated waters should be followed, but the risk of serious infection is not as great. These waters are usually not as unpleasant to dive in as severely contaminated sewage water because the concentrations of pollutants of a corrosive or anoxic character are not so great.

8.3.10. Reactor shielding tanks

Diving in reactor shielding tanks is only carried out when the reactor has been defueled or prior to fueling; there is therefore no danger from excess heat. Most work is of an inspection and repair nature and is thus of an entirely commercial character. The only hazard is remnant radioactivity, and levels are measured using a dosimeter carried by the diver; a dipped dosimeter is often used in planning the course of a dive as it can be placed in positions that the diver will occupy and the radioactivity levels of the dive can be calculated. All diving is tethered with a surface attendant in constant voice communication.

Many large, and some small specialty, diving companies carry out industrial diving in reactor shielding vessels, and scientists wishing to dive in these sites should consult with these companies. Ideally, the scientist should be able to work with the company personnel in carrying out the scientific work with the normal commercial back-up; these are not low-cost diving sites.

8.3.11. Offshore platforms

The presence of the structure itself is the principal factor in determining the safety of diving from offshore platforms. The platform, which is expensive, is not there for its own sake but usually for some industrial or other purpose. The platform is usually associated with a complex of instruments, projecting arms, cables, wires and drilling equipment. A diver swimming into this maze of engineering needs to be fully acquainted with the distribution of equipment. Knowledge of the geometry of the platform and its superstructure is mandatory, especially in low visibility conditions. It is often best to work from inside the frame of the structure, which may be the space most free of wires and cables. In all work scenarios entanglement is a serious risk. Changing tides, currents and the passage of fronts can cause the water to accelerate and change direction suddenly as it passes through and around the frame members.

Photo 11: Diving from offshore platforms requires detailed planning. *Photo: G. Stanton*

When a task has to be performed on or near a submerged structure or platform, there must be an extremely detailed plan of the activity to be carried out underwater. This should be limited to a simple job objective for each dive. The surface team and the divers must have detailed instructions and communication between diver and the surface must be carefully defined in the absence of a telephone link.

Diving may be carried out from small oceanographic platforms, experimental engineering or research platforms, or operational oil platforms. If scientific divers are required to work from an oil industry platform, it is probable that they will have to comply with the industrial and commercial diving regulations.

Where petroleum exploration, development drilling or production is being carried out from a platform, the conduct of diving must be very carefully phased so as not to interfere with work. In some cases this will mean that diving has to be carried out while industrial operations are continued, producing considerable noise and vibration underwater. Great care should be taken to ensure that diving operations are only carried out when there is no risk from heavy equipment or machinery moving underwater.

All diving operations from platforms should additionally be supported by a small boat. This is a great help when the divers need to exchange tools, adjust instruments, bring up samples, etc. Furthermore, in the event of an emergency, a small boat can track the diver, while support personnel on the platform obviously cannot move. In stormy conditions it can be difficult for the divers to approach fixed members of the platform, and it is much safer to home onto a support boat.

Platforms often attract submarine life, including large fish and possibly sharks. Noise may help to keep them away, but this is more than compensated for by the usual attractions of food, garbage, etc. that is discharged into the sea from a platform. Divers working around platforms should always be watching for sharks. In the event of injury to a diver working on a platform far from shore, it may not be possible to evacuate the diver in bad weather (6.3.5; 8.2.15).

8.3.12. Electrical fields

Installations producing pulsed or varying electrical fields such as screens, barriers or 'guides' to control the movement of aquatic animals, and impressed current anti-corrosion cathodic protection systems are the main source of hazard to the diver (Shilling et al., 1976; Mole, 1984). Electrical systems for guiding fish are fortunately used very little either inland or on the coast, primarily because they consume a great deal of electrical power. Inland electrical-fishing operations are associated with groups of people, wires, generators and often non-metallic boats. Military areas where electrical systems may be used are best avoided unless there is full co-operation.

General: The physiological effects of electrical fields increase progressively with increasing field strength and depend on the direction of the diver's body within the field. The direct effect upon the body of electrical shock is related to the magnitude of the current passing through the body, especially the heart. This is known to be variable between people, and there is much variation in data published on the effects. However, the diver may sense the effect of an electrical field or observe progressively erratic behaviour of a compass or of fish. The effects of increased field strength and likely body current can be divided into three main reaction groups:

1. The first reaction or perception threshold or shock with no loss of muscular control, while in fish fright and discouragement are observed. This first reaction is often associated with low frequency pulsed DC fields and large anodes (less than 10 mA DC, 2 mA at 60 Hz or 20 mA at 10 kHz).

2. Painful shock, difficulty in letting go or muscular contractions while in fish electrotaxis is observed. Electrotaxis is a mixed reaction of attraction or repulsion and is associated with forced swimming of mid-water fish. It varies with the direction of the DC electrical field and its strength. Alternating current, as opposed to pulsed direct current, is rarely used for electrofishing as it causes rigid muscular spasm or tetanus. This second reaction is often associated with high frequency pulsed fields set up within the water (less than around 100 mA DC, 25 mA at 60 Hz, 100 mA at 10 kHz).

3. Ventricular fibrillation or in fish electronarcosis, immobilization or with sufficient power or close proximity or contact, death by electrocution. This reaction is associated with short-term

contact or close proximity to large power sources (3 seconds duration; greater than around 500 mA at DC, 100 mA at 60 kHz, 500 mA at 10 kHz. Or 0.03 second duration, 1300 mA at DC, 100 mA at 60 kHz, 1100 mA at 10 kHz). The figures are taken from Haigh (1975), Smoot and Bentel (1971), Shilling et al. (1976) and Cromwell et al. (1973).

The conditions which influence the currents passing through the diver are influenced by a great variety of factors which include the water conditions (temperature and water chemistry, particularly conductivity), the electrical signal (frequency, shape and duration of pulse), the electrodes (size, shape, orientation and separation), the diver's orientation in the electrical field and the distance apart of wetted areas (wet v. dry suits).

Sites where electrical fields may be in operation comprise installations which are known to vary greatly in both the electrical power used and in the frequency of its pulsation or variation. They include:

1. Near intakes to pumps and turbines to prevent the entry of fish. They are commonly placed upstream of the main debris screens.

2. On complex watercourses or below dams to guide fish into 'passes' through or around obstacles.

3. Near channel entrances or exits to prevent the entry of intruder or unwanted aquatic animals.

4. On or around fish farms to isolate fish for management purposes.

5. In general where fish are required to be captured by stunning. This technique has also been used experimentally for fish shoal capture and the removal of burrowing animals. Recorders of fish activity or numbers by electrical methods are of little danger to the diver when functioning correctly, but can be associated with fish 'guides'.

6. Cathodic and Impressed Current Protection systems particularly on offshore installations.

7. Military and associated installations and vessels.

8. Proximity to large power carrying underwater cables.

The most obvious hazards are:

1. **When drifting with the current:** The diver may progressively be influenced by the electrical field and become unconscious or could be held on an electrode itself. This situation would include oblique or transverse pulse electrified screens in rivers or near fixed coastal installations.

2. **Installations being switched on during dive operations:** A locked-off key system must be used where this possibility is known to exist.

Although freshwater applications occur (their rarity may be a danger in itself), marine systems require large amounts of power and, except for cathodic protection, alternatives are normally sought. In general, there should be no diving if there is a significant electrical field, and if one is suspected, suitable precautions must be taken; the use of metal dive- boats must be avoided. The development of a suitable test meter is proposed.

The diver should try to maintain constant vigilance of unusual sensations when diving in unknown waters. Watch for unusual fish behaviour and be aware that electrical fields affects compasses, upsetting underwater navigation.

8.3.13. With large or dangerous animals in aquariums

The working divers at an oceanarium dive and work in controlled aquatic environments with a number of exotic species of animals, both mammals and fishes (8.2.12; 8.2.14). Many of these aquatic animals are, or can become, a threat to the uninformed diver.

Before entering any tank or facility with animals, talk to the handlers or curator to learn about the animals you are to dive with. If possible, identify each individual animal and obtain information about its specific behaviour and personality. The more you know about the specific animal's natural or learned behaviour, the safer you will be upon entering their environment.

1. **Behaviour of the species:** Learn the general behavioural characteristics of each animal species, especially larger fishes and sharks. Know antagonistic and aggressive postures and movements. Observe animals and note natural and unnatural movements.

2. **Physical capabilities:** Learn the physical capabilities and capacities of each animal species. Know the range of motion of the animal, i.e. up and down or side-to-side locomotion. Know the strength and speed at which it can move.

3. **Mating season:** Know the mating seasons of each animal species. Males especially become more aggressive, as will females. Male dolphins or manatees may even attempt to copulate with humans during this time.

4. **Females with young:** Female mammals will become aggressive in protecting their young. Do not make any attempt to move toward or touch newborn or young.

5. **Groups or single animals:** Know and understand the social structure or hierarchy system of a group of animals. This will help avoid confron- tations with the dominant animal.

6. **Length of time in captivity:** The longer an animal is in captivity, the less fear of man develops and they may become more aggressive. Also in an unnatural environment, unnatural behaviour may develop or be learned. This is especially true with the smaller dolphin or toothed whales.

7. **Climatic changes:** Temperature and barometric changes seem to affect animal behaviour. Cooler water can make animals more perky and aggressive while extremely warm water can make them irritable. Barometric pressure, along with extreme temperature changes can affect sharks and fish behaviour.

8. **Territorial behaviour:** Dolphins, whales and sea lions are territorial and may display aggression toward intruders.

9. **Newly rescued or injured animals:** An injured wild animal can be dangerous and unpredictable. The animal may or may not display aggression toward its captors owing to pain and/or fear.

Diving with animals other than sharks:

1. Upon entry, observe animals and watch for nervous or erratic behaviour.
2. Keep calm, swim slowly.
3. Once animals resume normal behaviour, you may proceed with task at hand.
4. Watch for agitation among the animals while you work.

5. Never make a move toward an animal that may be interpreted by that individual animal as an aggressive action.

6. Aggressive warning signs, usually before physical harassment, may appear as jaw snaps, false charges, fast or erratic swimming, rigid body posture, etc. Exit the tank upon observing this behaviour.

7. Aggressive physical harassment by animals may appear as head butting, tail slapping or sometimes biting (mainly nipping bites with sea lions).

8. To leave the tank, swim along the bottom and up the side watching the animal as much as possible to fend off attack. Still do not take aggressive action. Swimming across the surface seems to be a submissive gesture and you may be subject to greater physical danger.

Diving with sharks (Also see 8.2.12):

1. Upon entry watch for nervous or erratic behaviour.

2. Be calm and swim slowly.

3. Do not block the path of or corner a shark.

4. Never enter a tank with open wounds or pass body wastes once you are in.

5. Aggressive warning signs such as rigid body, arched back pectoral fins pointed down and exaggerated swimming action are but a few signs. Once these signs are observed you should leave the tank as fast but as quietly as possible with no splashing. Splashing and fast, abrupt movements on or underwater emits low frequency sound vibrations which will attract the sharks.

6. In the event of attack:

a. Face the shark as much as possible while leaving.

b.If more than one shark, crawl along the bottom then up the side.

c.If the shark comes in for an attack, bring your knees up to your chest and kick him off. Preferably be on top of him and kick down or underneath and kick up. The shark can spin around much faster than he can move up or down because their locomotion is from side to side. The eyes and gill slits are also vulnerable and can be punched or jabbed to ward off attack.

d.Always carry bang sticks or shark billys for defence and use a shark cage when possible. There is little defence against a shark that is intent on the kill.

Remember that you are there on the animal's terms, not yours. You must respect and obey their rules.

8.3.14. Shipping lanes and fishing grounds

If possible, the relevant local and national authorities must be notified well in advance so that 'notices to mariners' can be issued. This may be a legal requirement in some areas. Diving anywhere near fishing grounds can cause problems both for the diving party and the fishermen. As part of the pre-dive planning, the local fisheries' officer or the local fishing co-op or fisherman's organization must be informed. It is courteous to inform the local fishermen individually insofar as this is possible. Finding out the normal hours that fishermen plan on being in an area will allow the divers to try and dive during hours when fishing is at a minimum. Don't bother asking fishermen to change their schedules to suit the diving.

Divers must either tow marker buoys or descend buoyed shot-lines. They must surface up these lines and must signal the surface of their intention to ascend. An affirmative reply must be received before ascent commences. In addition, there should be some remote method of signaling the diver either to stay down or surface. The use of an underwater voice communications system is highly recommended.

Whenever possible, diving should be conducted from a mother ship with a dinghy keeping close station on the divers. Appropriate signals must be hoisted. The support boat should carry radar reflectors. A radar check must be kept aboard the mother ship by the officer of the watch.

Diving involving decompression stops is not recommended as rapid recall of divers may be necessary with the approach of a vessel.

8.3.15. Subterranean artificial environments

Background: Some experiments require large tanks underground or in enclosed environments, such as an excavated cavern or mineshaft. This example is provided.

In an effort to provide experimental data on the matter of proton decay, a theorized mechanism of sub-atomic particle behaviour, a test tank 80 by 70 by 60 ft deep, containing 10,000 tons of ultra-pure reverse-osmosis water was constructed in 1981 in a working salt mine near Cleveland, Ohio. It was necessary to choose a site at considerable depth (2,000 ft below ground) in order to provide some shielding from background cosmic rays that would otherwise interfere with the experiment.

The tank was constructed by excavating a hole of the proper dimension and lining it with a double layer of 2.5 mm high density polyethylene. By pumping the water collected between the liners, it is possible to know very accurately the amount of leakage (if any). A floating ceiling of black Hypalon was placed over the tank to ensure total darkness when the detector operates. Two thousand forty eight photomultiplier tubes, each 8 inches in diameter and fitted with a 1 m2 plate of light gathering plastic, line each of the six sides of this cube-shaped tank.

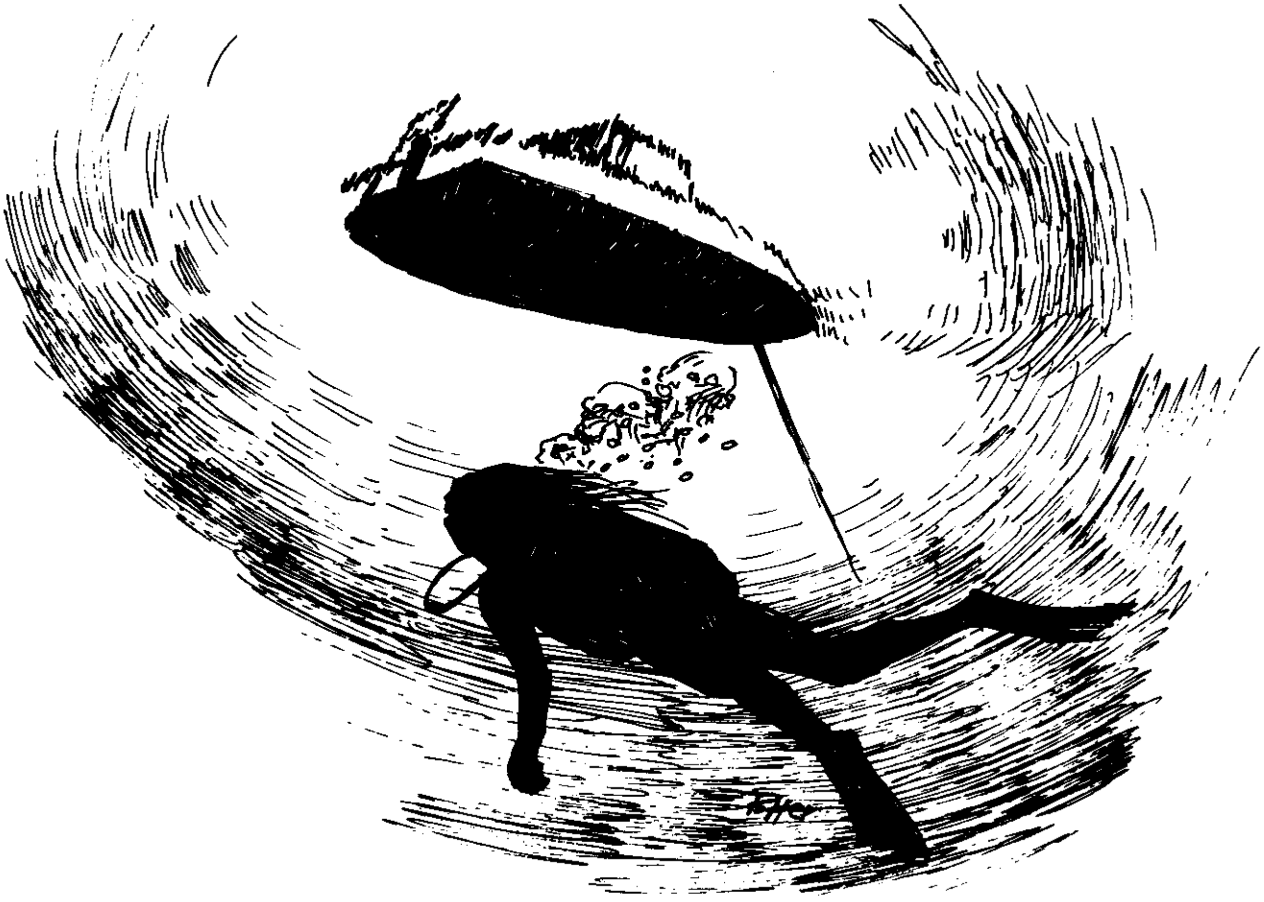
Establishment of diving operations: Following early successful support efforts, it became clear that diving would be necessary on a routine basis, not just in the installation phase. A diving team was built up, conforming to the university diving program.

Equipment specifically suited to the needs of the project was purchased and stored on-site to ease mobilization and to minimize the opportunities of contamination of the water. Equipment chosen included Viking (bag) dry suits, full-face masks with communications, dual 80 cubic foot tanks and a lightweight umbilical consisting of a safety-line with a communications conductor threaded through it. A compressor was placed on-site.

Current procedures: The proton decay (PDK) dive team is made up of university students and employees who must meet all the requirements set forth by the diving safety committee.

Additionally, PDK divers are trained in the specifics of the task (diving in enclosed space, entanglement potential, blackout potential, contamination avoidance, etc.). Special attention is also paid to safety requirements set down by the Federal Mine Safety and Health Administration and the owners of the salt mine in which the experiment is located. The use of mine safety equipment (hard hats, battery lamps, carbon monoxide scrubbers, safety shoes, ID tags, etc.) is also necessary. For those divers regularly visiting the site, special courses in mine safety and first-aid must be scheduled and completed.

Diving is limited to no-decompression profiles and a 10-ft safety or precautionary stop is taken at the end of each dive. Because of the higher than normal air pressure above the dive tank, adherence to decompression table times introduces a safety factor. The tender makes regular air pressure checks and records the progress of the dive on a prepared form which becomes part of the permanent record.



SECTION 9. BOATS AND SUPPORT EQUIPMENT

9.1. Introduction

All divers who are carrying out regular diving operations should familiarize themselves with both large and small boat operations as their knowledge will raise the level of safety. This section is not intended to be a substitute for the many excellent manuals on seamanship and boathandling courses; these should be used in conjunction with this Code of Practice along with any regulations or institute instructions for the operation of diver's boats. Divers should be trained in boathandling and inshore navigation.

9.2. Suitable vessels and support boats

Three sizes of craft will be considered: Small boats for direct close support of divers; motor launches or craft up to 10-20 m in length that can provide support facilities, storage, etc. for a day or more of diving operations in coastal waters; and sea-going and ocean-going vessels.

1. Whether in the open sea or in coastal waters, divers shall normally be attended by a small boat. This small boat may be dispensed with only when diving near the shore in clear, calm water with negligible currents. The small boat should be easily and safely entered from the water by divers, and will be fitted with waterline hand holds strong enough to take the weight of the fully-kitted diver (6.2.5). The boat will be stable and ride the sea without wallowing, and it must have positive buoyancy in several sections so that it cannot sink even if holed; this applies to solid, semi-solid and inflatable boats.

The type of small boat usually found most suitable for diving is either an inflatable with a hard floor or a flat-bottomed dory of from 3-5 m in length. It should be powered by an outboard engine of between 25 hp and 40 hp which is suitable for extended running at or near the idle position as well as being able to keep running at higher revs without overheating. A motor with two cylinders and a remote fuel tank is recommended. A smaller spare engine should be carried if the boat is working alone, and any running engine should be bolted to the transom or secured to the transom with a strong line. At least double the expected fuel expenditure should be carried. Switch-over of fuel tanks should be made with the first tank on half to ensure return if the spare fuel is contaminated. Fuel should be run out of the tanks in staggered order based on the most recently mixed fuel available. A pair of oars should be carried.

2. The most suitable motor vessel for a small diving group is about 10 m long, with a small cabin, large cockpit, inboard (diesel) engine and preferably with a propeller guard but without a deep keel. An inflatable or dinghy should be carried or towed (6.2.5; 6.2.6). Larger vessels of 10-20 meters in length can provide support, transport, accommodation, compressor, etc. for several days or weeks of diving in coastal waters.

3. A large diving support ship (6.2.6) shall have a means of safely and rapidly launching a small boat. A sling must be securely attached, preferably to rigid parts of the small boat and not to eyes fixed to rubber patches.

A number of ships, particularly those with larger complements, are now using sewage plants in which several tons of sewage are stored in a caustic solution before being automatically discharged, complete with the caustic solution. This could be a serious hazard to a surfaced diver and arrangements must be made with the officer of the watch to prevent discharge while diving operations are in progress (8.3.6).

9.3. Safety equipment carried on board

An experienced coxswain, who shall be responsible for the dive boat, must remain in the boat throughout the course of the diving. It is recommended that the coxswain take no part in the diving, but commonly members of the diving team will take turns as the coxswain or boatman, as equally the divers also act as divers' assistants and boat crewmen to set and raise the anchor or shot-line. It is also desirable to have snorkel cover available in the boat to assist the divers on the surface, particularly if they have brought to the surface heavy or bulky specimens.

The boat will carry a suitable anchor or anchors to deal with the range of bottoms likely to be found; normally a length of chain and weights will be fitted above the anchor. The end of the anchor rope must be attached to the boat by eye-splice and/or snap-clips.

The boat should carry a securely attached watertight emergency box or boxes carrying:

1. In-date distress parachute or rocket and smoke flares; weighted thunderflashes where allowed, but these may be considered as explosives and not allowed in some countries.

2. A spare spark plug and plug spanner, water repellent (WD-40 or silica spray), split and shear pins and a length of narrow rubber tubing sufficient to be used as a fuel line on the engine block.

3. Spare starter cord.

4. Basic tools for dealing with the engine and boat (e.g. screwdriver, adjustable spanners, pliers, thin-bladed knife) as well as with the regulators and harnesses of the diving gear. Serious maintenance such as repairing cameras, should be left until return to the support ship or land base.

5. A small but comprehensive first-aid kit.

6. A card carrying the information important to post-dive safety (6.3).

7. A repair kit and suitable foot or hand pumps in the case of an inflatable.

8. A small bottle of medical oxygen and a resuscitation mask to be used only for dealing with a decompression sickness emergency.

9. A radio with appropriate frequencies should now be carried on any scientific diving boat.

10. The boat should carry an appropriate diver's flag and display it only when divers are in the water.

11. A boat shall carry a compass, chart and navigation light or lights appropriate to the boat's length if operating at night or in fog. A collapsible radar reflector is recommended.

Additional items are required when working in remote areas or other special or extreme conditions (8), and care should be taken by the Diving Officer to ensure that all possible boat-items are available and in working order. Many lists of equipment, often recommending proprietary brands, are published.

It is the responsibility of the Dive Marshal and Dive Leader to check the emergency box and other boat equipment before each diving day and at each change of diving group on the boat.

When the divers are down, the boat should remain close at hand and on watch so that the divers can be picked up as soon as possible on surfacing. If there is to be any doubt about the position of the divers when near the boat (e.g. in surface water of low visibility), the propeller will be at rest unless fitted with a propeller guard.

The boat, particularly if it is a fiberglass dory, should not be overloaded and should be kept as tidy as possible (6.2.5).

Except in conditions of absolute safety, all passengers and crew in a small boat should wear buoyancy aids or diving or exposure suits.

In the case of an inflatable, it is important that equipment does not chafe the floats. This can be achieved by means of an interior canvas lining to the boat and by careful stowage of gear.

9.4. Range of operating conditions

Depending on the type and size of boat and motor being used, the level of teamwork and the physical capabilities of the diving party, as well as the nature of the scientific work, the range of operating conditions will vary.

Some boats are much more capable in bad weather than others, i.e a Zodiac MK IIIGR with a 35-40 hp motor is much more seaworthy than a Zodiac MK IIC with a 15 hp motor and the working limits of the basic boat provides the primary constraint. On the other hand, the MK IIIGR cannot make rapid way in sea conditions much above those associated with force 5 winds, whereas an Avon 5 m Searider can make excellent way and possibly provides even a better diving platform, except for the low transom that causes the boat to be rather easily flooded. Maximum operating conditions for a diving boat will largely depend on its size and power. For instance, 16 ft RNLI (UK) inshore rescue inflatables with 40 hp engines are not permitted to operate more than 5 miles (8 km) from the coast or in wind force exceeding 6. This is a maximum for an emergency service and routine diving operations should be well within this limit. Smaller and less well engined boats will have substantially lower limits.

Diving from a large launch or specially designed diving vessel can be managed in very bad sea conditions but the divers can be in some danger in the immediate vicinity of the boat. In bad conditions no diving boat should be anchored, especially when divers are in the water, unless there has been or is liable to be an engine failure.

Experienced divers operating with proven equipment can work safely in conditions that would be hazardous for less well prepared divers.

Some operational requirements are:

1. Limits of weather and sea state should be stated in the operational instructions for each project as each diving area will be subject to somewhat different conditions because of local protection and back-up.

2. If there is any possibility of deteriorating conditions while divers are down, a rapid recall system must be available.

3. It is the Dive Marshal's responsibility to satisfy himself as to weather outlook, including listening to the broadcast forecast for shipping. Weather services will often be ready to supply detailed forecasts for a particular area on request, and this service should be used, if possible.

4. In poor conditions, operations should be cancelled or suspended well before they become dangerous. It is the responsibility of the Dive Leader in charge to use judgement.

9.5. Diver recovery aids (Also see 6.3.1; 6.3.2)

A diving boat, if anchored on dive station must be moored in such a way as to be able to slip immediately, e.g. by buoying the anchor line. When operating in currents, a downstream float and floating line of adequate length will be trailed from the boat if it is anchored or from the shot-line buoy (8.2.8) if the boat is manoeuvering. A diving boat will have adequate water-level hand holds and will be fitted with a diver's ladder for ease of boarding. Divers should practice the technique of getting into an inflatable unaided and with no ladder as they are otherwise helpless alongside an unmanned boat. A short, but blunt boat hook for pulling the diver in can be put on the handle end of an oar/paddle and can be useful for reaching a rope or a diver.

9.6. On-board compression chambers

Because of their size, bulk and the cost of operating them safely, on- board compression chambers are only found on large ships (8.3.6). The presence of an on-board compression chamber is advisable and even a legal responsibility for certain types of diving, especially in remote areas or in blue water diving well away from a compression chamber on land. The chamber should be at least two compartments with a double airlock entry chamber into a larger chamber that can be entered for shorter periods by medical and other personnel. Standard sets of this equipment are commercially available and back-up and operating systems are all well established. If a chamber is to be used, at least two members of a diving team must be trained in its operation.

One-person transportable chambers must only be used if there is a guaranteed system of rapid transport to a fully supported two-compartment chamber facility and the proven capacity to transfer an injured diver under pressure.


Potter

SECTION 10. SPECIAL EQUIPMENT

This section discusses some special types of experimental equipment that scientific divers may need to use from time to time.

10.1. Towed sledges

Diving on a towed sledge may be necessary when it is important for a diver to study or inspect some object moving in the water faster than he/she can swim, or faster than an unstreamlined diver/DPV vehicle. A sledge also provides the means to survey or photograph rapidly very large areas of the seabed. The divers are usually shelter behind a streamlined fairing that allows them to pass through the water at speeds that would tear off their equipment if they were not so sheltered.

Vehicles without a buoyancy control must only be used when the maximum seabed depth is within a safe diving depth. This type of vehicle cannot be used over very deep water, since in the case of the towing vessel stopping, the towed vehicle would tend to sink steadily with the divers.

Vehicles with a buoyancy control can be trimmed to stay at a safe diving depth, but most work within the 'no decompression limits'. This would allow a buoyancy controlled vehicle to work over deep water when necessary.

Ideally, vehicles should carry two divers.

Vehicles should carry the following safety equipment and have the appropriate back-up facilities:

1. A location device should be fitted to the vehicle, i.e. a pinger, for which a locator is held in immediate readiness for the back-up team, so that the vehicle could be quickly located in case the tow-line breaks.

2. Communication to the towing vessel by line or through water must be provided for both occupants.

3. Communication must also be possible between the occupants in the vehicle.

4. An emergency breathing system should be fitted for both occupants in the vehicle.

The divers should check the vehicle and equipment before it is deployed and again after they enter the water prior to diving. Following positive checks and a clear signal from the divers, the surface controller should then give clearance and permission for the dive to start.

Occupants should wear scuba diving equipment so they can leave at any time while under tow and ascend to the surface in an emergency. Divers should normally remain with the vehicle until it has surfaced and the safety boat closed up.

Monitoring should be carried out by the surface control team of diving times, depth, positioning of the vehicle and the comfort of the divers in relation to cold.

Vehicle occupants must have complete over-all control of a dive unless there is a breakdown in communications where the surface controller would take over and take appropriate action to continue or terminate the dive.

A cover boat must be in position well astern of the towing vessel and equipped with radio for communications to the towing vessel. The divers' cover boat will display the diver's flag and should carry an emergency and first-aid kit.

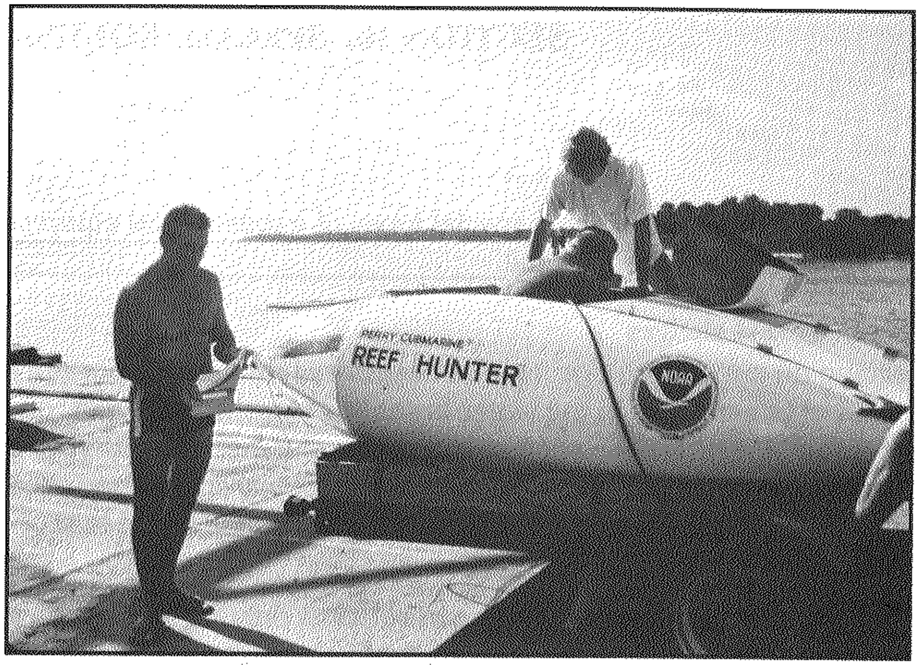


Photo 12: Diver propulsion vehicles (DVPs) such as this one come in a variety of shapes, sizes, and methods of propulsion. Proper training and planning are essential for using them safetly. *Photo: G. Stanton*

The towing vessel should warn other vessels in the area to stay clear and give a wide berth while diving is in operation. Appropriate diving, towing signals and lights must be shown.

If for some reason the ship stops, the vehicle must be able to return to the surface on the maximum length of the cable deployed using its own buoyancy and at the correct rate of ascent for normal scuba diving.

Adequate protection against the cold must be provided, i.e. uni-suits or dry suits with thermal underwear; the divers may be in the water a long time with little activity.

Basic training should be provided in the handling techniques of the vehicle.

The task to be attempted must be fully discussed and understood by both divers and controllers including the skipper.

Divers should not be attached to the vehicle by buddy lines. The exception is where the diver is connected by a communication cable and these should have McMurdo-type plugs and sockets where quick release is possible.

Trailing marker lines from a vehicle is not always practicable or advisable and especially when working with fishing gear, pingers must be an accepted alternative.

Divers should not enter a towed vehicle until it has been deployed and is well away from the towing vessel.

10.2. Wet-diver transport vehicles, diver propulsion vehicles (DPV)

Diver propulsion vehicles have their own power units and are steered by the diver altering the position of his/her body and fins. The speed may vary, but the diver is usually moved directly through the water as there is rarely a faring to provide for shelter or streamlining. More elaborate DPVs that the diver can actually get into are really mini-submarines.

Since the introduction of free diving, a range of submersible vehicles designed for the transportation of scuba divers with and without additional equipment has been developed for sport, military and commercial purposes. Although their utilization has been limited, there are definite areas of underwater activity that benefit from their application. The Farallon Diver Propulsion Vehicle is probably the most successful and well known DPV, although many other manufacturers also produce similar vehicles. These vehicles are used for towing divers on survey, inspection and exploratory dives for an hour or more at speeds of 1-3 knots. More sophisticated vehicles, which enclose the diver and offer protection from cold, drag and dangerous predators, are also available in limited numbers but are more often designed and built individually by institutions or enthusiasts. If the application of a diver transport device is contemplated then the following points should be taken into consideration:

1. **Discipline.** Submersible vehicle operations must be disciplined with an accepted set of rules to ensure the safety of those involved.

2. **Chain of command.** This should be composed of experienced and competent personnel to ensure proper vehicle maintenance, dive planning and operational and emergency procedures. Factors to be taken into account include overall safety of the mission, liaison with support vessels and shore support, battery charging and vehicle preparation, vehicle launch, dive and recovery, personnel briefings, pilot and crew endurance, crew experience and emergency arrangements.

3. **Pilots and crew.** Pilots should be experienced divers with good understanding of their environment, have an aptitude for mechanical and electrical systems and be familiar with the complete submersible system. The pilot should be responsible for the pre- and post-dive checks. Crew members must be familiar with the emergency procedures. Rapid ascents and descents should be avoided as ear clearing can be difficult if both the diver's hands are engaged on the DPV.

4. **Dive planning.** This should take into consideration the location and environmental conditions, the dive objective, the schedule, special mission needs, safety considerations, communications, vehicle and crew endurance, weather and tides, water depth and topography, known hazards, water temperature, emergency procedures, etc.

5. **Support vessel.** It must be available to stand by and track the DPV from launch until safe retrieval. Tracking a marker float is quite realistic in water free from obstructions and of limited depth. Sea state limits for launch and retrieval should be established. Surface visibility of less than one mile (1.6 km) should prohibit submersible operations.

6. **Check list.** The more sophisticated the vehicle is the more elaborate the check list required, but even the most simple of vehicles should have a fixed routine to avoid battery gas hazards and accidental floodings.

7. **Submersible/DPV.** Maximum dive duration should be established as should emergency reserves of power which should not be used for any other purpose. Speed should be restricted within the visibility limitations of the water. Dive times and ascent rates must never exceed those of normal scuba diving practice. Operational range must not exceed that of clear communication between the submersible and the support vessel. Post-operational debriefing must highlight any equipment malfunction which should be corrected before a further dive.

8. **Vehicle design.** The design should minimize the possibility of entanglement. Emergency power and deballasting facilities should be provided. Battery compartments must have gas

tight integrity from switch gear and other electrics. Batteries should have emergency isolators, circuit breakers and be appropriately fused. Battery compartments should be well ventilated for charging and preferably purged with nitrogen before closing or opening. An explosimeter can be used to test for hazardous gas mixtures. Do not underestimate the dangers from either a short circuit or gas emission. Consider static and dynamic stabilities of the completed vehicle and crew both at the surface and underwater. Consider vehicle drag, total battery power required, control surfaces, buoyancy and trim control, waterproofing techniques, instrumentation, ergonomics, payload and safety from electrical shock (8.3.12; 10.5.1).

9. **Operating procedures.** Procedures should be established for: Battery charging and dive preparation, launching, communication and tracking, surfacing, recovery and towing.

10. **Emergency procedures.** Procedures should be established for: Vehicle loss underwater and at the surface, electrical failure or fire, flooding, entanglement, HP air loss, loss of surface contact, diver loss and vehicle out of control.

11. **Safety equipment.** To be considered would include: Radio Direction Finder (RDF) Beacon, xenon strobe light, pinger, lifting lines, marker lines and buoys and portable transceiver radio kept in a waterproof container for emergency use on the surface.

10.3. Remote controlled vehicles (RCV)

These are also known as remotely operated vehicles (ROV). Divers are commonly employed around RCVs when they are being placed into the water and when they are being taken out. Once they are lowered into the water and the lifting gear is released, often by divers during the course of inspection check-out, the RCV descends under remote control from the mother vessel. Divers may once again be used when the RCV comes to the surface in order to ensure that the lifting harness is properly connected and that the RCV is safe to lift.

Use of divers in the vicinity of RCVs must be closely controlled as the personnel controlling the vehicle are usually out of sight of the vehicle, as the control room is often within the ship or in a windowless container console on deck. Because the thrusters on the RCV can cause serious injury to a diver, the handling operations must be part of a well ordered drill, controlled from the deck of the mother vessel by a controller who is in visual contact with the divers and with telephone communications to the control room.

A small RCV with lights and video-camera, sometimes known as a 'flying eyeball', can work efficiently with divers, providing an overview for topside supervision, work guidance and safety.

10.4. Use of explosives

Blasting can be a quick and convenient means for many underwater operations. These include deepening rivers and channels, cutting piles and dispersing wrecks. The use of explosives underwater is complicated by the necessity for special waterproofing precautions, especially where electrical shotfiring is used, by the difficulty of placing explosives charges most effectively and by the weight of the overlying water. These difficulties are more than offset by a considerable economy in labour and the great saving in time in which the operations can be completed.

Special attention may be required in underwater blasting to ensure that there is no excessive vibration or shock which might cause damage to neighboring structures or equipment. This is because water and water-bearing deposits are very effective transmitters of shock waves. Where the explosives are placed in shotholes, the chief factor will be ground vibration, but with unconfined charges the effect of the water-borne shock will predominate.

Divers handling explosives should attend a recognized course on explosives at a suitable military or civilian establishment. Normal precautions for handling explosives should be taken.

The peculiar effects of underwater explosions are summarized by Shilling et al. (1976) and the US Navy Diving Manual (1979). Any person exposed to an underwater blast of any severity should receive medical attention, whether or not he/she seems to be injured. Internal damage can be serious with no superficial symptoms.

Storage and detonators: There is a danger that stray electric currents near outboard engines or electrical equipment may accidentally set off a detonator. Always short out detonators by twisting the lead wires together. Store the detonators as far away from the actual explosives and electrical sources as possible. Hand-operated exploders are safer than batteries, but if batteries are used keep them in a dry box with a lid. Fuse-ignited detonators are more shock sensitive than electric detonators. These should be kept in the manufacturer's cartons within a box that will resist fragmentation. Quantities carried should be kept to a minimum.

Procedure: Charges must be made up on the surface; the person making up a charge in a boat should wear no diving equipment other than a suit. Great care should be taken to check the whereabouts of divers since a mistaken diver count could lead to a diver being in the water when a charge is detonated. It is probably best for a single diver to lay the charge and to be solely responsible for detonating it. Care should be taken that a boat does not drift over a charge before it is detonated. Most divers swim with a left or right bias; make sure that the diver setting the charge has not swum full circle laying the charge under the boat. When the diver has placed the charge and left the water, only then should the other end of the cable be connected to the exploder at the firing station, and the shot fired.

If the diver is to return to the unfired charge, first disconnect the cable from the exploder. In the event of a misfire great care must be observed. No person shall be allowed near a charge unless it has exploded or until an interval has elapsed of not less than 30 minutes in the case of firing by fuse, or 10 minutes in the case of firing by electricity.

General recommendations for shotfirers:

1. Do not store explosives, detonators, etc. except in a proper magazine which is clean, dry, well ventilated, well constructed and properly locked.
2. Explosives and detonators must be stored separately, either in separate magazines or in a compartmented magazine. In this connection it should be noted that detonating fuses should be stored with the explosives.
3. Do not smoke or allow any matches or open lights in or near the magazine or while handling explosives and detonators.
4. Do not keep any metal tools in a magazine, and only wooden tools should be used for opening cases.
5. Do not drop or slide cases of explosives or handle them roughly.
6. Issue explosives and detonators in the sequence of manufacturing dates marked on the cases.
7. Do not open cases inside the magazine.
8. When a case has been opened, its contents should be used before opening another case.
9. Do not make up primer cartridges inside a magazine.

10. As in storage, boxes of explosives and detonators must not be transported with anything else such as metallic tools and inflammable liquids.
11. Where feasible, explosives and detonators should be conveyed in separate vehicles or carried by different people. If both have to be carried in the same vehicle or by the same person, they must be placed in separate containers or in one container that is adequately partitioned.
12. Again as for the magazine operations, when unloading the boxes or containers from the vehicles or when setting them down, they should never be slid on the ground or over one another. Each should be lifted carefully and put down without shock and never dropped or thrown about.

Instructions for blasting operations must be directed by an experienced person fully qualified to do so. Detailed inquiries can best be dealt with on an individual basis. Scientific divers who wish to involve blasting in their work can refer to appropriate military or civilian personnel.

Table 10-1 shows explosives that are recommended for underwater use.

10.5. Use of electricity underwater in equipment and experiments

Underwater electrical equipment (10.2; 10.3) introduces hazards to scientific diving (8.3.12).

Water, particularly if it is salty, is a moderate conductor of electricity. There is, then, an apparent hazard to divers and submersible pilots who have to work with electrically controlled equipment. However, it can be safe to use electricity underwater (8.3.12).

The most obvious dangers from electricity underwater is electric shock from a malfunctioning or improperly grounded apparatus. When using any electrical gear underwater, therefore, it is imperative that the equipment be thoroughly tested before it is deployed for use, and then used only in the precise manner that it was designed for. Electric shock can come from either a generator or battery source and it should be noted that a 48-volt battery for a DPV can often deliver a more serious shock than a 120 or 220 line voltage because of the higher amperage loading of the batteries.

10.5.1. Units powered from surface or remote batteries

If the casing of the electrical apparatus is metallic, it should be electrically continuous and should be adequately earthed (grounded) by a suitable electrode at the battery or generator end of the system. Conventional overcurrent protection, preferably supplemented by earth leakage trips provides a similar safety factor to that of earthed (grounded) hand tools used outdoors on the surface. A system using an isolation transformer and amplified differential earth leakage protection is preferred. A limit of 5 mA tripping current is suggested. If false tripping occurs at this level it indicates inadequate insulation in either the cable or apparatus. The possibility of using intrinsically safe supplies (i.e. those employing potentials below the limiting value) exists but care must be taken to use design information obtained from a reputable source.

10.5.2. Units powered by self-contained batteries

Self-powered units present an electrical and explosive hazard. Batteries should be connected just before use and disconnected as soon after use as possible.

Electrical hazards: If the case is either metallic and electrically continuous or insulating, then even in the event of implosion the risk of dangerous external fields is minimal. Care must

Table 10-1. Explosives recommended for underwater use

Product	Description	Cartridge Diameter	Head of Water (depth)	Duration of Immersion
'Subaq' 90	High density, high strength gelatinous explosive. Plastic cartridges with built-in channel for detonator leads or 'Cordtex'	63mm/2.5in (140 ft)	Down to 43m	Several days
'Subgel'	High density, high strength gelatinous explosive. Plastic cartridges with built-in channel for detonator leads or 'Cordtex'	63mm/2.5in (150 ft) or more	Down to 46m	Several weeks
Special Gelatine 80% & 90% Seismic Gelatine	Medium density, medium strength gelatinous explosives.Paper chipboard cartridges	All sizes	Down to 6m (20 ft)	A few days
Opencast Gelignite	High density, high strength gelatinous explosive. Chipboard cartridges	70mm/2.75in	Down to 30m (100 ft)	A few days
Plaster Gelatine	High density, high strength gelatinous explosive. Paper/ polythene wrapped slabs	Various slab and cartridge sizes	Down to 46m (150 ft) or more	Several weeks
Submarine Blasting Gelatine	High density, high strength gelatinous explosive.Paper and chipboard cartridges	All sizes	Down to 450m (1500 ft) or more	Several weeks

be taken if attempts are made to salvage such items as it may take several hours for the batteries to discharge.

Explosive hazards: The risk of explosion is considered to be the main hazard with self-powered units.

Many batteries (even when described as sealed) evolve hydrogen at times. Table 10-2 indicates when this may happen. Unless nitrogen or oil immersion is used, all such units should be opened when on charge and after use in the water. H_2 plus O_2 is the explosive mixture resulting from an evolution of H_2 into an air filled compartment. The opening of all underwater battery compartments must be carried out in the open air away from any burning material and very hot surfaces. Once air flushing has been carried out, the vehicle can be reassembled but not sealed, and the small amounts of H2 that may evolve after discharge should dissipate without danger as long as the batteries are in a well-ventilated place.

Additionally, protection against sparks may be obtained by using magnetically operated reed switches. As very considerable quantities of hydrogen can be evolved from a battery discharged to a level where the weakest cell is reversed biased, it is strongly recommended that a circuit be incorporated to isolate the batteries when their Electromotive Force (EMF) falls below a predetermined level.

Table 10-2. Evolution of gases from batteries

Battery	Under Charge	Normal Discharge	Discharged flat-so that some cells may reverse bias
Lead Acid	$H_2 + 0_2$	H_2	$H_2 + 0_2$
Ni-Cd	$H_2 + 0_2$	None	$H_2 + 0_2$
Sealed Ni-Cd	Possibly H_2	None	Possible H_2

10.5.3. Other hazards with batteries

Emission of toxic fumes can be a problem associated with various batteries. Good ventilation is always sufficient to deal with this problem.

Fumes from overheated insulation may be a problem, but dangerous plastics that evolve poisonous or carcinogenic gases under high temperatures are now only commonly found on older insulation. Diving Officers should inspect the wiring and the age of the equipment to assess the likelihood of this problem with their equipment.

All electrical equipment should be inspected from time to time and at the first sign of trouble should be subjected to replacement or very thorough service and further inspection.

A code of practice for use of electricity underwater has been published by CIRIA (1982).

10.5.4. Precautions when handling equipment on boat or surface

Divers and personnel with wet hands should not be allowed to handle batteries and electrical apparatus on the surface. Potentials that are not dangerous or even detectable to persons with dry hands may be dangerous to a diver whose skin is soaked with salt water.

10.6. Use of radioisotopes and radioactive chemicals

This section is concerned with biological and, possibly, some geological experiments in which material is exposed to radioisotopes in relatively small, sealed containers underwater or as low-activity sediment tracers. Experiments where large amounts of radioisotopes are administered to open systems are not considered and would require special authorization should they be justified.

10.6.1. Relevant authorities and literature

The use of radioisotopes in most countries is strictly controlled by a large amount of legislation concerned with handling, storage and transportation of the materials (Appendix 2). Divers wishing to use radioisotopes should make reference to appropriate governmental or other national authority that is charged with supervision of radioisotopes. Nuclear energy boards, departments of energy, ministries of health, radiochemical inspectorates or other agencies can be identified within most countries.

10.6.2. Legal requirements and recommendations

The project must have the prior approval of the national controlling authority, usually your own laboratory radiation protection officer. The site or area where you propose to work and the isotopes to be used must be registered with the appropriate government authority. Overseas work must conform to any local regulations, which are best interpreted and implemented with the help of a local institute.

Personnel must be designated radiation workers, or at least registered under a scheme approved by your laboratory, and they should all have prior experience of using the radioisotopes in question in the laboratory before using them underwater.

Amounts and kinds of radioisotopes used must be covered by a government Registration Certificate (where appropriate), and final disposal must be at a place and in the ways allowed by a Certificate of Authorization for the Disposal of Radioactive Waste.

There are strict laws governing transportation and packaging of radioisotopes while in transit, especially in North America and Europe. Also, make sure that you and your vehicle are insured while carrying and using radioisotopes.

10.6.3. Accidental spillage or loss of radioactive samples

Consider the following points carefully:

1. Is there any possibility of spillage, either at the surface or underwater, from an unsealed isotope source due to equipment malfunction or breakage? Samples are most at risk when being handled at the air-water interface, especially on a rocky shore, and also in small boats in rough weather. If spillage occurs, is there any danger to public water or food supplies, or to the environment by localized concentration via the food chain?

2. Can the containers with radioactive materials be readily relocated and recovered under most weather conditions, to prevent loss of radio- isotopes on the seabed, or will they stay in place for later recovery without risk of displacement or washing ashore? Mark them conspicuously in case this should happen.

3. Are the containers so stowed during underwater transportation as to allow the diver to jettison them safely for later recovery should difficulties arise?

10.6.4. Protection of divers from radiation sources

Experiments using beta-emitting isotopes such as carbon-14, calcium-45 and phosphorus-32 are relatively safe. There is little risk to the divers from the external radiation itself since water is a good absorber of beta-particles, although the stronger emitters such as P-32 may give a large radiation dose if contained in a thin-walled vessel held in the hand. The sea also offers a vast dilution ratio should accidental spillage occur underwater. Amounts of radioisotopes should be kept to a minimum - not more than a few millicuries in any experiment - and special consideration should be given to work in freshwater environments in view of the possible subsequent uses of the water. For this reason use the isotope with the shortest half-life that is practicable.

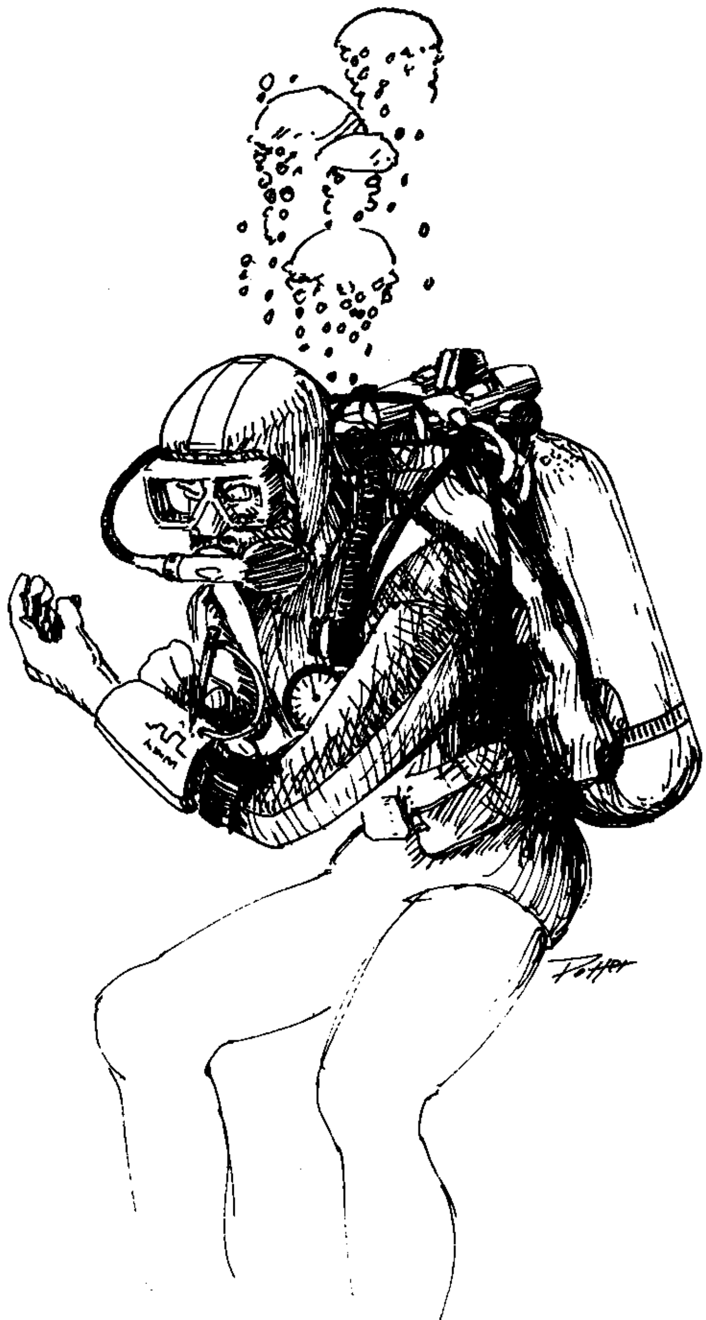
No experience has yet been gained using gamma emitters, such as the biologically interesting metals, in underwater experiments. However, if these are planned, it must be remembered that water is not a good absorber for such radiations and further shielding such as lead will be required underwater as well as on land. Divers will also require waterproofed safety film badges for such work; these can readily be adapted from those used in the laboratory.

10.6.5. Disposal of waste

Remember that a large amount of water may have to be transported back to the laboratory after the experiments, for authorized disposal. Therefore take sufficient strong containers and conspicuously labelled packaging for this. The same applies to all solid waste and to other materials such as preserved experimental material and samples for analysis.

10.7. Use of acoustic energy

Most acoustic devices, echo-sounders, range-finders, directional beacons, etc. radiate so little power as to be completely harmless. However, there are acoustic systems used in geophysical research, long-range sonar, and military acoustic systems that radiate power at an intensity that could be harmful to divers in the water. When divers are likely to be working near such systems the Chief Diver/Diving Officer should establish contact with the operators of the systems and ensure that power is not radiated during diving.



SECTION 11. DECOMPRESSION

11.1 Introduction

In all institutions where scientific diving is conducted, there should be a recommended set of decompression tables, approved by the Diving Officer or the Diving Control Board, which are compatible with national legislation. All the tables mentioned specifically in this section are acceptable, but the list is not exhaustive. There are other tables, some of which may be mandatory in some countries. In this chapter the most commonly used tables are compared for some of their characteristics, with particular reference to the tables generated in the USA and the UK. It is assumed that the Diving Officer has standard diving manuals, published decompression tables and information on the conduct of decompression dives. This chapter outlines the present state of knowledge with regard to decompression diving shallower than 50 m and is intended to help divers to use decompression procedures in the most intelligent way. This section should be read in addition to standard diving manuals, not as a substitute.

It would appear at first sight a simple matter to detail the variables involved in the decompression phase of a dive and give firm advice about decompression procedures. However, the development of non-invasive methods for the detection of gas phase separation within the body has greatly increased our awareness of the complexity of decompression. Unfortunately, it also indicates that a good deal of the confident advice given in the past can now be seen to be misguided. Perhaps the best example of this is the detection of bubbles, and even outright decompression sickness, after repeated breath-hold dives (Paulev, 1965). It is essential for everyone involved in diving to be aware of the unpredictability of decompression sickness and to recognize that the risk is present in virtually all diving.

From recent research it is now apparent that the safety of the final decompression of a dive is dependent upon the conduct of the dive itself. To understand the basis of this statement, it is necessary to study briefly the stages of a dive.

11.2 The compression phase

As a descent is made, the increased partial pressures of the components of the breathing gas, that is, with compressed air, oxygen and nitrogen, result in more of both gases dissolving in lung tissue and being transferred to the blood. The dissolved gases are then transported by the blood to the body tissues, where they will increase the dissolved gas content or tension. The amount that will dissolve, that is, the dose of nitrogen per unit volume of tissue, will depend not only upon the time at depth, but also upon a considerable number of other variables, including the level of exercise during the dive. Exercise increases cardiac output and reduces circulation time. Tissues, of course, have widely differing levels of blood flow and even within a given area of a single tissue, the blood flow may not be constant. The tissues are also not homogeneous and may contain zones of differing fat content and therefore differing gas solubilities.

When Haldane (1907) calculated his original air tables, he allowed for the uptake of gases in five different tissues, by a series of exponential curves. He assumed that the release of gas during decompression followed the same profiles. In other words the uptake and off-gassing of a tissue would be symmetrical. His calculations also assumed that a degree of tissue gas supersaturation could be allowed on decompression, without the formation of gas phase, based upon a 'no-stop' decompression depth. Haldane and co-workers established this depth for compressed air, from a rather small number of exposures, as being 42 ft (about 13 m) of sea water. When the partial pressure of oxygen is subtracted from this absolute pressure, the nitrogen partial pressure is 2 ATA. It was therefore argued that if, during decompression, the tissue supersaturation did not exceed a value twice the absolute pressure, then no symptoms would arise. Unfortunately, this argument was later amended to the two to one decompression ratio not being associated with any release of gas from solution (Haldane, 1922).

Two observations now indicate that the method is flawed and, in fairness to Haldane, a study of the original papers shows that he was aware of the limitations of this approach. They are, first, the detection of gas by ultrasound during decompression after exposures well within the 'no-stop' decompression limits (Eckenhoff et al., 1986), and second, the demonstration of intermittent blood flow within tissues. The separation of gas from solution prevents the accurate computation of gas transfer by the Haldanian method, which, of course, must assume that the gas is all in solution. This phase separation ensures that the rate of gas elimination will always be slower than the rate of uptake. Intermittent perfusion of tissue, that is the sequencing of blood flow, is common in many tissues, but now has been found to occur in connective (including muscle) tissue (Hills, 1979), which is the tissue most likely to be involved in the pain of simple decompression sickness.

Until this information became available, it seemed logical that minimizing the time at maximum depth, and therefore reducing the 'dose' of nitrogen (determined by the product of the partial pressure of nitrogen and a function of time) would minimize the risk of decompression sickness. However, this can be seen to be only partly true, because, if there are a number of significant ascents from the maximum depth during the dive, gas phase will be present before the final decompression. The risk of decompression sickness will then be much greater.

It must always be remembered that, for ethical reasons, the end-point in titrating decompression tables has been joint pain, that is 'Type 1' decompression sickness. However, Hills (1971) has shown than in deep, short duration air dives, serious decompression sickness may develop in the absence of joint pain.

11.3. The decompression phase

A significant ascent is one that exceeds the upward excursion allowed by the partial pressure vacancy created by the metabolic usage of oxygen. This effect, termed the 'oxygen window' by Momsen and Behnke (1938), occurs because the fall in the tissue gas tension of oxygen is not accompanied by an equivalent rise in the carbon dioxide tension.

The gas tension values for air expressed in millimeters of mercury (mm) at normal atmospheric pressure (1 ATA) are:

Table 11-1. Arterial and venous gas tension values

IN ARTERIAL BLOOD:			
	P_mO_2	=	100
(P_m = Arterial gas tension)	P_mCO_2	=	40
	P_mN_2	=	573
	P_mH_2O	=	47
Total arterial gas tension =	760 mm Hg.		
IN VENOUS BLOOD:			
	P_vO_2	=	40
(P_v = Venous gas tension)	P_vCO_2	=	45
	P_vN_2	=	573
	P_vH_2O	=	47
Total venous gas tension =	705 mm Hg.		

The difference, 55 mm Hg at 1 ATA, has been termed the 'inherent unsaturation' by Hills and LeMessurier (1967), and they have demonstrated the effect experimentally. As the partial pressure of the oxygen in the respired gas is increased, up to an as yet undetermined point, the inherent unsaturation is also increased. For example, at 50 m breathing compressed air, the partial pressure of oxygen is about 1.2 ATA and the calculated undersaturation is 723 mm Hg. This means that an upward excursion of almost 10 m is possible without the risk of gas separation. Any further ascent will be accompanied by supersaturation and some gas phase separation. However, this does not mean that the diver will develop decompression sickness. A diver who has gas in a critical tissue, like the spinal cord causing paraplegia, may have less gas separated from solution than a diver who has no symptoms. In other words, the absolute amount of gas separated from solution may be relatively unimportant, and a comparatively small amount of gas in a vulnerable site is capable of producing dramatic and permanent disability.

11.4. Standard air decompression

Decompression tables are based on general principles, modified and developed by experience. The only proof of the worth of a procedure is the accumulation of actual diving experience. It is most important that proven procedures are used. As military diving has been a major force in the development of tables, a great deal of data on their performance has been collected and analyzed. In the present chapter comments have been directed to the US Navy and Royal Navy tables, but it must be remembered that the French Ministère du Travail Tables (1977) are also widely used. It must be accepted that risk acceptance in military procedures may differ from that regarded as acceptable in civilian life. The following general principles will help to minimize the risk of decompression sickness, but it must be accepted that, for most dives, it is not possible to make a bubble-free ascent in any reasonable time scale. Wherever possible dives should be planned within the 'no-stop' decompression limits.

1. Bottom time must be logged from the start of the descent to the beginning of the ascent, and the bottom depth is the maximum depth of the dive.

2. When planning a dive involving work at widely different levels, it should be programmed to start shallow and work downward. This will slightly increase the nitrogen uptake, but prevents the separation of gas from solution, before the final ascent.

3. If upward ascents must be made during the bottom time, they should be limited, whenever possible, by the decompression allowable within the inherent unsaturation.

4. The time at the first stop is reckoned from the beginning of the ascent to the beginning of the ascent to the second stop.

5. The times at the second and subsequent stops are reckoned from the start of the ascent from the previous stop to the start of the ascent to the next stop.

6. The stoppage depths must be as accurate as possible. If there is an underwater structure, then the depths can be marked. If a shot-line is used, it must be correctly weighted and accurately marked with a measurement at the diver's chest. Care must be taken to allow for any deviation from the vertical.

7. Many tables do not allow for hard work. When a dive is strenuous, decompress for the next bottom time entry in the tables.

8. The ascent rates used in tables are important and undoubtedly have contributed to the success of a given procedure. The recommended rates of ascent must be used. They depend to some extent on the tables being used:

Table 11-2. Diving table ascent rates. All rates of ascent are for sea water. Detailed instructions are found in table procedures for dealing with deviations from the recommended rates of ascent.

a.	US Navy	60 feet per minute
b.	RN Air Table BR 2806 Table II	20 meters per minute
c.	RNPL/BSAC Air Diving Decompression Table 1975	15 meters per minute
d.	RNPL Metric Air Diving Table 1976	15 meters per minute
e.	French, Ministère du Travail, 1977	15 meters per minute
f.	Canadian Forces Air Diving Tables Tables and Procedures 1986	60±10 feet per minute

These rates are to be used from the end of the dive and also for ascents between stops.

9. The maximum depth, when compressed air is being used, should be limited to 50 m, but there are variations in national legislation that may further limit depth.

Notes on the above. The requirement to log the pressure exposure profile of the diver is important. The maximum depth must be recorded, and the time of start of the ascent. If microprocessor instruments are being used that predict the optimum dive profile, but do not record the actual dive, then the dives should be logged and recorded in the diver's personal logbook. Recommendation (2) above introduces concepts that are the opposite of those used in electronic decompression computers presently available. These computers are based on equations that do not allow for gas phase separation caused by shallow ascents preceding the final decompression. For an irregular profile dive, they therefore compute the minimum total decompression time for a dive that has the deepest part first, followed by a gradual ascent (6.2.19; 11.8). Physiological data indicate that Recommendation (2) above is the safer procedure. Recommendations (4, 5 and 6) require adherence to a known decompression profile, with the result that the diver's final exposure both during gas up-take and gas release is known and recorded. Decompression computers presently available do not record these data, and therefore there is no check on the diver's true nitrogen loading.

11.5. Diving in remote areas

In remote areas dives requiring decompression stops should not be attempted. In exceptional circumstances, where such a decompression dive is planned, special arrangements should be made. Planning must include arrangements for transportation and for conveying a decompression casualty to a compression chamber. It must be emphasized that pulmonary barotrauma with gas embolism is an ever-present risk, especially with inexperienced divers. Flight in some pressurized or unpressurized aircraft may exacerbate decompression illness.

Table 11-3. Dive character and compression chamber requirements

Max. operating depth of dive	Operational Conditions	Type of Compression Chamber (Minimum requirement)
1. 0-10 m	All	None - but divers must be aware of the nearest chamber.
2. 10-50 m	Short duration dives, stops unlikely to exceed 20 minutes.	Within 2 hours' traveling time of a two compartment chamber BIBS* O_2.
3. 10-50 m	Stops regularly being used.	Two compartment chamber on site. BIBS* O_2.
4. Surface	All decompression	Two compartment chamber on site. BIBS* O2.

* Indicates a Built-in-Breathing System

11.6. Post-dive precautions

A diver who has carried out a dive where stops have been used to depths of 50 m (approximately 165 ft) should remain within one hour's travelling time of a working compression chamber for 12 hours after completion of the dive.

It is advisable that divers in post-decompression periods should carry a card, giving information that they have dived and who to contact in the event of illness.

11.7. Decompression tables

Air diving tables are available from many sources both military and commercial. The majority are based on the Haldanian calculation method, but some now use deeper stoppages employing a more thermodynamic approach. Recently an evaluation of four military tables has been reported (Masurel et al., 1986), for an exposure of 50 minutes at 36 m. It illustrates that adding more stoppages may not improve the bubble-inhibiting character performance of a table.

The situation is complicated by the limitations of the Doppler ultra-sound system in use, which is only capable of detecting fairly large bubbles. The size distribution of the bubbles is a function of the extent of supersaturation induced and the amount of gas released, which is time-dependent. Finally there is the volume change induced by the expansion during the ascent according to Boyle's Law (James, 1983). As bubbles formed on a variable profile descent may not be reabsorbed completely at the maximum depth, but only compressed, prolonging bubble formation until the end of bottom time is important.

When comparing or judging tables it should be borne in mind that no table can possibly prevent decompression sickness entirely, and that the incidence of bends, and the incidence of different types of bends, may be judged to be more or less acceptable depending upon the surface support equipment available, and whether the divers are working in a military or civilian situation. To say that one set of tables is 'safer' than another can be a statistical statement of truth, and yet a Diving Officer or Diving Control Board may authorize the 'less safe' table, taking into account the other factors involved. The American, British and French tables mentioned in this section are all widely used, and comments on the safest table for any given exposure are based on statistical data.

The British RNPL/BSAC Air Diving Decompression Tables 1975 are very useful and fairly reliable for dives where decompression is less than 31 minutes, otherwise the full RNPL Metric Air Diving Tables, 1976, are probably the safest option.

The US Navy tables are less reliable, particularly on longer and/or deeper dives in excess of 35 minutes.

11.8. Repetitive diving

A repetitive dive is rather arbitrarily defined as a second exposure to pressure, within a period of 16 hours (12 hours in the US Navy Tables) after surfacing from the first dive.

The RNPL Metric Air Diving Tables, 1976, only consider double dives, and decompression on the second dive must be carried out for the bottom depth of the deeper of the two dives. Some allowance is made for the surface interval between dives; the longer the surface interval, the smaller the fraction of the first dive bottom time that has to be added to that of the second dive. The resulting sum is used to calculate the decompression required on the second dive.

With this system, it is clearly advantageous that the longer dive should be done first, since in this way the calculated equivalent bottom time, and hence the decompression time, of the second dive, will be minimized. On the other hand, if one of the dives is a deep dive and the other is a shallow dive, it is more natural to do the deep dive first, because decompression for the first dive will be occurring during the second shallower dive, but not vice versa. Unfortunately though, a heavy decompression penalty must be paid on the second dive using these double dive rules, if the first dive is short and deep, even for large surface intervals, since decompression must still be carried out as for the depth of the deeper of the two. Another discontinuity in the use of these double dive rules is that, while a second dive to a depth of 9 m or less is not considered a second dive, a dive to 10 m is, and a heavy decompression penalty accrues if the first dive is deep or long.

The US Navy Tables have been in widespread use, because of the convenience of their repeat dive and surface interval credit tables. Safe decompression on these tables is possible for some combinations of double dives, but in practice it appears that longer and/or deeper and multiple dives, using these tables, are unsafe on a statistical basis for dives working without the support of an on-site recompression chamber.

The RNPL double dive rules are very safe, but have a number of inconvenient discontinuities. The US Navy repetitive tables are more consistent and permit multiple dives, but are less safe for certain dive combinations.

Inevitably in practical diving circumstances arise that carry substantial risks, which nevertheless are allowed by the tables, for example:

1. Multiple dives all within the no-stop limit. As already indicated, multiple breath-hold dives can give rise to decompression sickness. The explanation lies in the redistribution of gas released by the first, or subsequent decompressions, in the next dive, that is the next compression and the residual dissolved tissue gas. The redistribution of intravascular bubbles through the trap imposed by the lungs may allow central nervous system decompression sickness to develop.

2. Constant diving or multiple repetitive dives, which again may be allowable under the rules of a procedure, cause a slow build-up of tissue inert gas, both in solution and as gas phase and increase the risk of decompression sickness.

3. Long-duration dives, for example up to eight hours at depths down to about 10 m, may be undertaken in safety, but again care must be taken to limit the extent and number of upward excursions during the dive. Recent research has indicated that, although bubbles were produced after 48 hours exposure to 1.77 ATA, (7.77 m or 25.5 ft sea water) decompression sickness did not develop (Eckenhoff et al., 1986). Fifteen subjects were used in the experiment. It must be emphasized that when bubbles can be detected, there is always the risk of symptoms, and that these experiments were conducted under ideal conditions. It will be almost inevitable that long duration dives will be undertaken using a diving system or habitat (7.4). In such circumstances modest extensions of the no-stop decompression limits may be made using oxygen enrichment. However, oxygen toxicity restricts long-term exposures to partial pressures of oxygen less than 0.5 ATA. Decompression may be assisted by oxygen breathing during the final ascent to the surface.

11.9. Surface decompression

This procedure derives from military diving, where heavy salvage work in very cold conditions required the diver to be removed from the water. The technique causes an unacceptably high rate of decompression sickness affecting the nervous system and should be avoided wherever possible. If circumstances dictate the use of surface decompression, the British RNPL Tables are safer than those of the US Navy.

11.10. Diving and altitude

Travel to altitudes in excess of 1000 ft whether by surface transport or aircraft should be avoided for 12 hours post-dive. Exercise in the same altitude should be avoided for 24 hours. Diving at altitude is a complex matter but again experience of tables has accumulated in certain countries, like Switzerland, over a period of years and these tables should be consulted for guidance (8.2.1).

11.11. Exercise post-dive

It is well established that exercise releases gas into the circulation following a dive and whenever gas is present there is a risk of decompression sickness. This would indicate that passive transport, for example, a car or bus, carries less risk than a strenuous walk.

11.12. Helium and oxygen mixture diving

Helium is less soluble in the body than nitrogen, so for a given dive using an 80% helium, 20% oxygen mixture, compared to the same dive using compressed air, the body will contain much less helium than nitrogen. This is particularly important in relation to the nervous system, because most of the difference in the lesser quantity of helium is accounted for by the much lower solubility of the helium in fat. The nervous system, especially the spinal cord contains a great deal of structural fat. Helium and oxygen diving is much less likely to give rise to decompression sickness involving the nervous system (Behnke and Yarbrough, 1938; James, 1981).

11.13. Decompression sickness

The risk of decompression sickness can be minimized, but not eliminated by observing the following principles:

1. All significant reductions in pressure form gas phase, it is not practical to ascend so slowly that gas phase does not form.

2. The greater the reduction in pressure, the larger the amount of gas likely to separate from solution.

3. The risk of problems, that is, both decompression sickness and barotrauma, increases closer to the surface.

4. Decompression tables control the development of symptoms, not necessarily the release of gas.

5. Decompression sickness may develop, even when procedures are followed correctly.

6. No method is available to predict which diver will develop symptoms.

7. Serious symptoms may be much less dramatic in onset than simple decompression sickness.

8. It may not be possible to determine, in the presence of serious symptoms, whether the diver has embolism or decompression sickness.

11.13.1. Classification of decompression sickness

The classical division of decompression sickness into simple (Type 1) and serious (Type 2), originates from the Admiralty report on compressed air illness of 1907 (Haldane, 1907). It is important to recognize that Types 1 and 2 do not indicate a progression. There are very adequate reasons for regarding the mechanisms as distinct.

11.13.1.1. Simple decompression sickness: Type 1

Pain at the site of a joint and skin rashes. The pain is localized at the site and the diver is usually able to point to the specific area. It has been found in aviation studies that the local pressure from a blood pressure cuff could relieve the discomfort, if it was used immediately. Additional evidence from X-ray studies in aviators (Webb, et al., 1944) and in animal experiments (Hills, 1979) have confirmed that gas in tight connective tissue is responsible for the pain.

Pain in other sites is much more likely to be referred pain from serious problems in the nervous system. For example, low back pain associated with girdle discomfort, in a band extending round the body, or pain in the mid-thigh position.

Skin rashes are due to the blockage of capillaries and lymphaie by bubbles and the release of substances that cause the redness and itch to develop. Experience indicates that rashes may be accompanied by nervous system decompression sickness.

11.13.1.2. Serious decompression sickness: Type 2

Acute respiratory distress, the 'chokes', is due to the entrapment of bubbles in the lung and correlates with the bubble count in the pulmonary artery detected by Doppler ultra-sound. Severe forms are usually associated with a gross omission of decompression and may lead to sudden death. Milder forms often subside without treatment, but this is no reason not to initiate therapy. Abnormal fatigue is often present when the lungs are trapping an excessive number of bubbles. Very often respiratory symptoms are followed by the development of neurological decompression sickness.

The presentation of neurological decompression sickness can involve any nerve function. Because of the need for immediate treatment, it is essential that symptoms involving the nervous system be recognized and urgent advice sought. The presentations can include loss of consciousness, headache, vertigo, loss of hearing, disturbances in vision, weakness, paralysis and loss or disturbances of sensation.

Events leading to neurological decompression sickness are controversial, but evidence is emerging to support arterial bubbles, related to the failure of pulmonary entrapment, as the mechanism. The additional risk associated with air diving is likely to be due to the augmentation of bubbles lodging in a tissue with a high nitrogen content. A major problem for the arterial hypothesis has been the apparent absence of a non-diving related nervous system disease associated with microembolism, resulting from failure of pulmonary entrapment. However, there is now substantial evidence indicating that multiple sclerosis is due to this form of microembolism (James, 1982). Most cases of spinal cord decompression sickness will have experienced symptoms referable to the brain. Many of the presentations of decompression sickness, said to be related to the inner ear apparatus, are actually due to problems in either the brain stem or cerebellum. Occasionally symptoms due to brain damage involving cranial nerve pathways persist, as for example, in the eye or balance problems (Lieppman, 1981). Research is beginning to confirm that neuro-psychological deficits occur in air divers (Peters et al., 1977).

A major problem with the presentation of neurological decompression sickness is that, apart from the onset of paralysis, the signs and symptoms, both to the diver and his companions, may be insidious and undramatic. Urgent action may appear to be essential when a diver is in severe pain, but this form of decompression sickness is unlikely to be associated with any permanent damage. However, if the treatment of severe neurological decompression sickness is delayed for more than a few minutes, permanent damage may occur (Palmer et al., 1981).

11.14. Therapy in decompression sickness

The treatment of decompression sickness is aimed at reducing or eliminating the amount of gas that has separated from solution and correcting secondary effects like tissue oedema, hypoxia and shock. It must be emphasized that serious decompression sickness is an extreme emergency and recompression should be undertaken as soon as possible.

There are four established elements, and one area which is controversial.

11.14.1. Recompression

This is the most important measure and should be used as soon as possible because it produces an immediate reduction in the volume of gas (Boyle's Law). It also creates a concentration gradient for the return of gas into solution (Henry's Law). The former is instantaneous, but the latter takes time. Using the same diluent inert gas as the dive, as, for example, using air recompression therapy for decompression sickness arising in air diving, is not very satisfactory, because the second recompression is reloading the body with the offending nitrogen. This is particularly true of the 6 ATA (165 ft, 50 m) recompression air tables, where the partial pressure of nitrogen is 4.8 ATA. This has led to the use of pure oxygen or a raised partial pressure of oxygen in treatment and the introduction of helium and oxygen mixtures in therapy.

11.14.2. Oxygen

Following the work of Behnke and Shaw (1937), and an analysis of the failure of the long air tables in the treatment of serious decompression sickness, the US Navy introduced the minimal recompression, oxygen breathing tables in 1965, known as Tables 5 and 6 (Goodman and Workman, 1965). By eliminating a diluent 'inert' gas and increasing the inherent unsaturation, the use of pure oxygen ensures the maximum gradient for the removal of nitrogen. Oxygen relieves localized hypoxia and also, by vasoconstriction, reduces secondary tissue swelling or oedema. However, the absolute pressure used is restricted by oxygen toxicity to 2.8 ATA, and oxygen at this level is implicated in other problems, recognized by the worsening of symptoms noted in the US Navy Manual. It must also be remembered that oxygen can contribute to the gas phase.

11.14.3. Helium and oxygen mixtures

Clearly if the 'depth' of the recompression therapy is restricted by oxygen toxicity, then it would be useful to add a diluent gas other than nitrogen. In commercial diving, helium and oxygen mixtures are generally available and are rapidly becoming standard therapy for compressed air decompression sickness. Following some experimental work in the early 1970s, there were fears that helium would amplify a gas phase containing nitrogen, but this is now known to be untrue. The procedures of the US Navy allow the use of 80% and 20% helium-oxygen mixtures in place of air in their treatment tables. However, it is dangerous when the gases are the other way round, that is, air should never be used for the therapy of helium-oxygen mixture divers.

11.14.4. Fluid therapy

It is now known that when the micro-bubbles released by decompression are present in blood vessels, they do not act as simple plugs or emboli. The bubble causes an increase in the permeability of the blood vessel wall, which is related to endothelial factors. This causes a loss of fluid from the circulation, and, under these conditions, red blood cells aggregate, greatly increasing the resistance to flow. The effect is rapidly reversed by the infusion of fluids into the circulation. Cases of severe decompression sickness will always benefit from an intravenous infusion, and the procedure is without hazard. Also an additional benefit derives from the expansion of the circulation by a solution with a relatively low gas content. Incidentally, the importance of fluid balance in preventing or alleviating decompression sickness is such that divers should never start a dive in a state of dehydration. Drinking plenty of water in the period before dives allows fluid balance to be maintained.

11.14.5. Drug therapy

This is a highly complex and controversial area. Only one clear recommendation can be made and it is for high-dose steroids, which are of value in the reduction of blood vessel permeability.

11.15. Recompression tables

The standard air tables should only be used if oxygen is not available. The table of preference for recompression breathing oxygen is US Navy Table 6 (Appendix 3). The air therapy procedures of the US Navy can also be employed using a mixture of 80% helium and 20% oxygen. This is a procedure recommended for serious symptoms, recurrence of symptoms or when the patient has difficulty breathing. Where symptoms are unresolved the patient should, whenever possible, be held at depth and specialized advice obtained.

11.16. Therapy in the absence of a recompression chamber

In some instances when diving, for example, in very remote areas, it will not be possible to transfer the casualty to a recompression facility. The casualty should be given oxygen and fluids, preferably by the intravenous route. Apparatus is now available to deliver oxygen through a demand valve and this should become standard equipment for every diving expedition. The purge button can allow assisted ventilation, which may be life-saving in cases of high spinal cord paralysis. The decision to attempt to evacuate to a recompression chamber depends upon the nature of the problem. A simple knee bend or skin rashes do not lead to any permanent damage and will resolve without therapy. Some cases of serious decompression sickness resolve spontaneously but given the initial presentation it is not possible to predict which will resolve and which will not. Every effort should be made to obtain recompression therapy for cases involving the nervous system and some useful benefit has been obtained after delays of many hours or even days.

SECTION 12. SITUATIONS NOT COVERED BY THIS CODE OF PRACTICE

The main purpose of the present Code is to provide guidance as to the best and safest practice already used by scientific divers in different countries. The advice is given in a form that should be compatible with differing statutory regimes and for differing environmental conditions. As far as possible the content is designed to be supplementary to other published manuals and safety codes. It is, of course, impossible to tabulate all the conditions and combinations of conditions that can arise in diving, let alone to anticipate all the complex technical tasks, which may be required of scientific divers in the future. It is therefore extremely important that there should be an approved procedure whereby the best practice for a new situation can be devised and tested as quickly as possible.

Where an institute or project leader finds that the work proposed requires divers to operate in conditions and circumstances not envisaged in this Code and to depart significantly from it, the Diving Officer, Chief Diver, or scientist involved should act as follows:

1. Take into account as far as possible all the recommendations of existing codes of practice, including this one.

2. Draft a full set of precise rules for the diving project envisaged, stating new training procedures for personnel, new equipment to be used, safety precautions, the exact routines and procedures to be used at sea in stages of the operation, and in anticipating possible failures, faults or accidents.

3. Ensure that the project rules are circulated to personnel involved in the project.

4. If further consultation and advice is required, the project plan and rules should be referred to the Diving Officers at several of the larger establishments listed in Appendix 1. Their advice may be of benefit in improving the plans, especially if divers can be located who have practical experience in the relevant conditions. This is a purely consultative arrangement to enable people to benefit from each other's diving experience.

5. If the proposed diving rules involve breach of statutory regulations in the country where diving is to take place, application should be made for an exemption to specified clauses of the regulations. It is reasonable for such exemption to be granted, provided that extra safety systems are introduced to compensate for the departure from normal regulations.

6. If new project rules for new circumstances or conditions would be of general value to other divers, the Diving Officers concerned are requested to send their recommendations to the Editors of the present Code for inclusion in future editions.

APPENDIX 1. DIRECTORY OF INSTITUTES WITH DIVING PROGRAMMES

This list is not meant to be exhaustive. The organizations on this list are those known to the editors and contributors to operate diving programs with six or more divers on either a permanent or temporary basis. See Appendices 4 and 5 for additional establishments of contributors and section contacts.

Anti-shark Measures Board, P.O. Box 2, Umhlanga Rocks 4320, South Africa.

Barologia, S.A. Society for Underwater Science, Oceanography Department, University of Cape Town, PB Rondesbosch 7700, South Africa.

Bristol, University of, Department of Geography, Bristol, UK.

British Antarctic Survey, Madingley Road, Cambridge, CB3 OET, UK.

British Columbia, University of, Diving Operations, Suite 50 - 2075 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 1W5.

Cape Town, University of, Research Diving Unit, Oceanography Department, P.O. Box Rondebosch 7700, South Africa.

Curator of Marine Archaeology, W.A. Museum, Beaufort St., Perth, Western Australia 6000.

Department of Agriculture and Fisheries for Scotland, Marine Laboratory, P.O. Box 101, Victoria Road, Aberdeen AB9 8DB, Scotland, UK.

Diving Division, Defence and Civil Institute of Environmental Medicine, 1133 Sheppard Ave. West, P.O. Box 2000, Downsview, Ontario M3M 3B9, Canada.

Durham, University of, Department of Botany, Science Laboratories, South Road, Durham DH1 3LE, UK.

Fairleigh Dickinson University, St. Croix, US Virgin Islands 00820.

Fisheries Research Division, Ministry of Agriculture and Fisheries, P.O. Box 19062, 327 Willis St., Wellington, New Zealand.

(The) Flinders University of South Australia, Bedford Park, South Australia 5042.

Gatty Marine Laboratory, St. Andrew's University, St. Andrews, Fife, Scotland, UK.

Heriot-Watt University, Biological Sciences Department, Chamber St., Edinburgh, Scotland, UK.

Institute of Geological Sciences, West Granton Road, Edinburgh 5, Scotland, UK.

Institute of Oceanographic Sciences, 1. Deacon Laboratory, Wormley, Godalming, Surrey. 2. Bidston, Bidston Observatory, Birkenhead, Cheshire, UK.

Institutt for kontinentalsokkelundersøkelser (Continental Shelf Institute), Norway, Håkon Magnussons gt., Postboks 1883, 7001 Trondheim, Norway.

Israel Oceanographic and Limnological Institute, P.O. Box 8040 Haifa 31080, Israel.

Istituto per lo Studio della Dinamica delle Grandi Masse, Palazzo Papadopoli, 1364 San Polo, Venezia, Italy.

James Cook University, School of Biological Sciences, P.O. Box 999, Townsville 4810, Queensland, Australia.

Japan Marine Science and Technology Centre, 2-15 Natsushima-Cho, Yokosuka-Shi, 237 Japan.

Laboratorio di Geologia Marina del CNR, Via Zamboni 65, 40127 Bologna, Italy.

Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, USA.

Lehrstuhl für Erdölgeologie, Sedimentologie und Meeresgeologie, Technische Universität Clausthal, Leibnizstrasse 10, 3392 Clausthal-Zellerfeld Germany.

MAFF, Fisheries Laboratory, Lowestoft, UK.

Marine Biological Association UK, Citadel Hill, Plymouth, Devon, UK.

Marine Laboratory, Port Erin, Isle of Man, UK.

Marine Science Laboratories, Menai Bridge, Anglesey, Wales, UK.

Miami, University of, School of Marine and Atmospheric Sciences, 10 Rickenbacker Causeway, Miami, Florida 33149, USA.

Natal, University of, Zoology Department, Durban 4001, South Africa.

National Research Institute for Oceanology, P.O. Box 320, Stellenbosch 7600, South Africa.

NOAA Environmental Research Laboratories, Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida 33149, USA.

Oceanographic Research Institute, 2 West Street, Durban 4001, South Africa.

Port Elizabeth Museum, Humewood, Port Elizabeth 6001, South Africa.

Port Elizabeth, University of, Zoology Department, P.O. Box 1600, Port Elizabeth 1600, South Africa.

Rhode Island, University of, Narragansett, Rhode Island 02882, USA.

San Diego State University, Department of Zoology, San Diego, California 92182, USA.

Scripps Institution of Oceanography, La Jolla, California 92037, USA.

Sea Fisheries Institute, P.O. Box X2, Roggebaai 8012, South Africa.

Senckenberg Institut, Schleusenstrasse 39a, 2940 Wilhelmshaven, Federal Republic of Germany.

Scottish Marine Biological Association (SMBA) Dunstaffnage Marine Research Laboratory, P.O. Box 3, Oban, Argyll,Scotland, UK.

South African Museum, Queen Victoria Street, Cape Town 8000, South Africa.

Southampton, University of, Department of Oceanography, Hants, SO9 5NH, UK.

Station Marine d'Endoume, rue de la Batterie des Lions, Marseille, 7e, France.

Stazione de Biologia Marina, Riva 7 Martiri 1364A, I-30122 Venezia, Italy.

Swansea, University College of, Department of Zoology, Singleton Park, Swansea, Glam. SA2 8PP. Wales, UK.

Tokai University, Orido, Shimizu-City, Japan 424.

Tromsø, University of, Institute of Biology and Geology, P. 6790, 9001 Tromsø, Norway.

Underwater Technology Group, Department of Mechanical Engineering, North East London Polytechnic, Longbridge Road, Dagenham, Essex RM8 2AS, UK.

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, USA.

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APPENDIX 3: REFERENCES TO DECOMPRESSION TABLES

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APPENDIX 5. SECTION CONTACTS

This list is not meant to be exhaustive. These individuals are those known to the editors as having contributed broadly to diving organizations and the writing of manuals and codes in their countries. The number in brackets refers to the section in which the contact has specific expertise within a broad area of experience.

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APPENDIX 6. ACCIDENT REPORTING FORMS

The following forms are examples of existing documents prepared for use in the USA and the UK. There is no internationally agreed upon form currently in use. Individual institutes may have their own forms that are based on local practice and legal requirements. The information required for medical, institutional and possible legal purposes should be no less than that asked for in these examples.

In case of accident: The accident reporting form that is certified by the Diving Control Board under whose auspices the diving is taking place, should be completed by witnesses as follows:

1. Each witness should complete and submit his/her report separately. Do not attempt to co-ordinate reports.

2. Complete only those sections of which you have knowledge. It is not necessary to fill in all sections.

3. Be as complete as possible with the knowledge you have.

4. If you have any additional knowledge pertinent to the accident that may not easily fit into one of the questions, indicate this in writing.

5. Indicate position of the victim and condition of all equipment you observed.

6. Do not remove any equipment from the scene of the accident. If it is necessary to remove the tank and regulator, carefully check position and type of straps and releases. Close all the valves and note the number of turns necessary to do so.

7. Each person taking any action in a fatal accident should ensure that details (in writing) of the action taken accompany the body or equipment (as applicable), and that a separate written report of such action is compiled. This applies to any and all action, e.g. unbuckling of a strap, turning air on or off, position of reserve valve, removing any item of equipment, etc. Each fact is potentially important.

8. It is especially important that all relevant information accompany the victim of a non-fatal accident. This information should be in writing and state the conditions of the accident, types of equipment used, depth and duration of use, instances of mouth-to-mouth resuscitation and external cardiac massage. Information of diet, rest, alcohol and medications within the 24 hours prior to the accident should also be included.

9. Complete procedures dealing with the reporting of accidents to comply with any legal requirements.

EXAMPLE 1

DAN DIVE ACCIDENT REPORTING FORM

BOX 3822 • DUKE UNIVERSITY MEDICAL CENTER
DURHAM, NORTH CAROLINA 27710
Information Mon.-Fri. 9-5 (E.T.) (919) 684-2948
Emergencies Only (919) 684-8111

DATE & TIME OF ACCIDENT
MONTH/DAY/YEAR ☐☐☐☐☐☐ Time ______ AM PM

IS THIS A FATALITY REPORT? ☐ YES ☐ NO

For DAN Office Use Only
CASE
SEVERITY CODE
BMI

1. PATIENT NAME LAST FIRST MI

2. OCCUPATION

3. ADDRESS STREET CITY ST ZIP

4. PATIENT PHONE (HOME) ___ - ___ - ____

5. PATIENT PHONE (WORK) ___ - ___ - ____

6. COUNTRY (IF NOT USA)

7. AGE YRS

8. SEX M or F

9. HEIGHT FT IN

10. WEIGHT LBS.

11. CERTIFYING AGENCY
A - PADI
B - NAUI
C - NASDS
D - YMCA
E - SSI
F - Other
G - None

12. CERTIFICATION LEVEL
A - Basic
B - Open Water
C - Advanced
D - Divemaster
E - Instructor
F - Commercial
G - Other
H - None

13. DAN MEMBER?
Y - Yes
N - No

14. YEARS DIVING
YEARS MONTHS

15. NUMBER OF DIVES MADE
Total
Previous 12 months

16. PREVIOUS DIVE ACCIDENTS
A - Possible DCS
B - DCS
C - AGE
D - Pul. barotrauma
E - None

17. CURRENT MEDICATIONS
Y or N
Prescription
Non-prescription
List ______

18. CIGARETTE USE
A - Presently
B - In past
C - Never
Packs per day
Years Smoking

19. PREVIOUS MAJOR ILLNESSES/ SURGERY
(Provide up to 3 responses)

A - Chest-lung
B - Asthma
C - Chest-heart
D - Gastrointestinal/Abdomen
E - Brain
F - Spine/Back
G - Limb or joint of DCS site
H - Circulation/Blood
I - Neurologic/Nervous system
J - Muscle/Skeleton system
K - Eye
L - Mental/Emotional
M - Other ______
N - None

Past:
A - 2-6 months
B - 7-12 months
C - 1-3 years
D - 2-5 years
E - 6+ years

List and describe specific problems:

______

20. CURRENT HEALTH PROBLEMS WITHIN PREVIOUS 2 MONTH
(Provide up to 3 responses)

A - Chest-lung
B - Asthma
C - Chest-heart
D - Gastrointestinal/Abdomen
E - Brain
F - Spine/Back
G - Limb or joint of DCS site
H - Circulation/Blood
I - Neurologic/Nervous system
J - Muscle/Skeleton system
K - Eye
L - Mental/Emotional
M - Other ______
N - None

List and describe specific problems or additional current medications:

______

PLEASE ATTACH SEPARATE SHEET FOR ADDITIONAL INFORMATION OR NARRATIVE.

I understand that the information in this form will be used for research purposes only, and that all personal information will be kept strictly **confidential**. I also understand that the Divers Alert Network may need to contact me in the future for clarification of information provided on this form.

______
Patient Signature

DIVE ACCIDENT

21. PURPOSE OF DIVE

☐ A - Pleasure
B - Work/Labor

22. DIVE ACTIVITY (up to 2 responses)

☐ ☐
A - Wreck
B - Cave
C - Night
D - Photography
E - Under Instruction
F - Providing Instruction
G - Spearfishing/ Game collecting
H - Sightseeing

23. ENVIRONMENT

☐ A - Freshwater
B - Saltwater

24. ALTITUDE OF DIVE

☐ A - Sea Level
B - > Sea Level but < 1000 ft.
C - >1000 ft.

25. Was this dive or dive series typical of your normal type of diving?

☐ Y - Yes
N - No

IF NO, Explain ____________________

____

26. DIVER'S PERCEPTION OF TEMPERATURE

☐ A - Cold
B - Hot
C - Comfortable

27. CURRENT STRENGTH

☐ A - Strong
B - Moderate
C - Mild
D - None

28. AIR SUPPLY

☐ A - Scuba Air
B - Surface Supply Air
C - Mixed gas
D - None/Breath-hold dive

29. AIR CONSUMPTION

☐ A - Ran low
B - Out of air
C - Not a problem
D - Buddy breathing (not octopus)

30. BUOYANCY PROBLEM

☐ Y - Yes
N - No

31. RAPID ASCENT

☐ Y - Yes
N - No

32. WITHIN LIMITS-Y or N

☐ Tables (which table ________)

or

☐ Computer (type ________)

33. TYPE OF SUIT

☐ A - Wet
B - Partial Wet
C - Dry
D - Lycra
E - Swim

34. EQUIPMENT USED ON DIVE: (please check all that apply)

☐ Depth gauge
☐ Timing device/watch
☐ Buoyancy vest
☐ BC Inflator hose in use
☐ Decompression computer

35. EQUIPMENT MALFUNCTION:

☐ ☐
A - None
B - Regulator
C - BC Vest
D - Weight belt
E - Dry suit
F - DC Computer
G - Inflator hose
H - Contaminated air supply
I - Equipment was not familiar to you.
J - Other

Reason: ________

____

____

36. TYPE OF DIVE

Y - Yes
N - No

☐ Single

☐ Repetitive

37. WOMEN, PLEASE RESPOND (up to 2 responses)

When the accident occurred, were you:

☐ ☐
A - Menstruating
B - On birth control medication
C - Pregnant
D None of the above

38. DIVE LOCATION:

State, Province, or Island: ________

Country or nearest country: ________

39. How long ago was your last Dive Trip/Series?

☐☐ Circle one: Days Weeks Months

40. STRENUOUS EXCERCISE

Y - Yes
N - No

☐ 24 hours predive

☐ During dive

☐ 6 hours postdive

41. PREDIVE HEALTH

☐ A - Nausea/ vomiting
B - Hangover
C - Diarrhea
D - Other

42. ALCOHOL

Please check: / Number of drinks, beers, or wine

☐ None
☐ Night Before ☐☐
☐ Predive ☐☐
☐ Between Dives ☐☐
☐ Post Dive ☐☐

43. RECREATIONAL DRUG USE

Prior to, between, or after dive

☐ Y - Yes
N - No

44. Do you consider yourself physically fit?

☐ Y - Yes
N - No

☐ Do you excercise on a weekly basis? (Y or N)

☐ # Days per week

45. FATIGUE OR LACK OF SLEEP PRIOR TO DIVE?

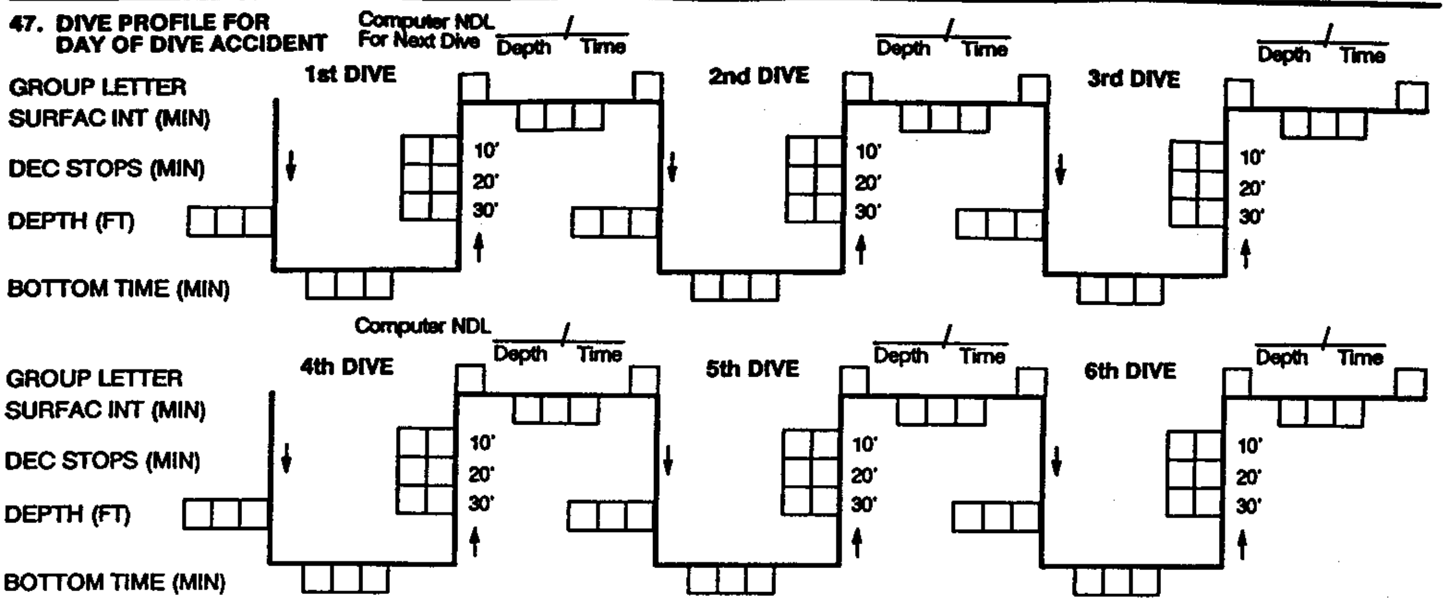
☐ Y - Yes
N - No

46. DIVE SERIES

Please fill in all that apply up to and including your last dive. If you skipped a day please leave that day blank.

	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
Total # of dives	☐	☐	☐	☐	☐	☐	☐
Any night dive? (How many)	☐	☐	☐	☐	☐	☐	☐
Any symptoms? (Y or N)	☐	☐	☐	☐	☐	☐	☐
A - All no stop dive(s) B - Any safety stop C - Any dive requiring decompression stops	☐	☐	☐	☐	☐	☐	☐
A - Multilevel (time divided) B - Square	☐	☐	☐	☐	☐	☐	☐
Deepest Dive (ft.)	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐

47. DIVE PROFILE FOR DAY OF DIVE ACCIDENT



PRE-CHAMBER INFORMATION

48. INITIAL CONTACT WAS:

☐ A - DAN Emergency
B - DAN Non-emergency
C - Hospital emergency room
D - Emergency medical service
E - US Coast Guard
F - Physician
G - Dive instructor/shop
H - Other: ____________

49. Total delay from symptom onset to contacting DAN or other medical help:

HOURS (Up to 72) ☐☐ DAYS ☐☐

50. FLYING OR INCREASED ELEVATION AFTER DIVING AND PRIOR TO TREATMENT?

☐ A - Commercial airliner
B - Unpressurized aircraft
C - Med Evac Flight
D - Mountain elevation
E - Does not apply

Hours post dive (flew or went into elevation) ☐☐

☐☐☐☐☐ elevation (in feet)

51. SYMPTOMS:

1st Symptom ☐
2nd Symptom ☐
3rd Symptom ☐
4th Symptom ☐
5th Symptom ☐
6th Symptom ☐

A - Pain
B - Rash
C - Itching
D - Weakness
E - Numbness/Tingling
F - Dizziness/Vertigo
G - Semi-consciousness
H - Unconsciousness
I - Restlessness
J - Extreme fatigue
K - Visual disturbance
L - Speech disturbance
M - Headache
N - Paralysis
O - Difficulty breathing
P - Nausea/Vomiting
Q - Hemoptosis/coughing blood from lungs
R - Muscle twitching
S - Convulsions
T - Hearing loss
U - Ringing ears
V - Decreased skin sensation
W - Bladder problem
X - Bowel problem
Y - Personality change
Z - Difficulty walking/standing
1 - Reflex change
2 - Other: ____________

52. LOCATION: Block A = location of symptom
Then please check (✓)
L = Left R = Right B = Bilateral/Both Sides

	A	L	R	B
1st Symptom	☐	☐	☐	☐
2nd Symptom	☐	☐	☐	☐
3rd Symptom	☐	☐	☐	☐
4th Symptom	☐	☐	☐	☐
5th Symptom	☐	☐	☐	☐
6th Symptom	☐	☐	☐	☐

A - Head
B - Face
C - Sinus
D - Eyes
E - Ears
F - Neck
G - Shoulder
H - Entire arm
I - Upper arm
J - Elbow
K - Forearm
L - Wrist
M - Hand
N - Fingers
O - Chest
P - Back
Q - Upper back
R - Lower back
S - Abdomen
T - Buttock
U - Groin
V - Hip
W - Entire leg
X - Thigh
Y - Knee
Z - Calf
1 - Shin
2 - Ankle
3 - Foot
4 - Toes
5 - Trunk
6 - Generalized
7 - Other: ____________

53. SYMPTOM ONSET:

	HOURS	MINUTES	or	BEFORE SURFACING FROM DIVE
1st Symptom	☐☐	☐☐		☐
2nd Symptom	☐☐	☐☐		☐
3rd Symptom	☐☐	☐☐		☐
4th Symptom	☐☐	☐☐		☐
5th Symptom	☐☐	☐☐		☐
6th Symptom	☐☐	☐☐		☐

54. ANY OF THE SYMPTOMS FROM #51 PRIOR TO THE LAST DIVE?

☐ Y - Yes
N - No

If yes, which symptoms?

1st ☐
2nd ☐
3rd ☐
4th ☐
5th ☐
6th ☐

Other ☐

Explain: ____________

55. FIRST AID ADMINISTERED BEFORE HOSPITAL OR CHAMBER HELP WAS RECEIVED?

Y - Yes
N - No

☐ Oxygen
☐ Aspirin
☐ Oral fluids
☐ Head down position/ Trendelenburg

If oxygen was received was delivery by:

☐ A - Demand valve
B - Freeflow valve
C - Don't know

PRE-CHAMBER INFORMATION (cont.)

56. HOSPITAL TREATMENT ADMINISTERED

(Please check all that apply):

☐ None ☐ Steroids
☐ Oral fluids ☐ Anticoagulant
☐ IV fluids ☐ Aspirin
☐ Oxygen ☐ Other medication

____
____

57. RELIEF BEFORE CHAMBER TREATMENT?

☐ A - Complete
B - Partial
C - Temporary
D - None

58. IF ANY RELIEF OCCURRED, WHICH SYMPTOMS FROM #51 ABOVE?
(Please check):

1st ☐
2nd ☐
3rd ☐
4th ☐
5th ☐
6th ☐

59. PRE-CHAMBER RELIEF OCCURRED:

☐ A - Without first aid or medical care
B - Following first aid
C - Following pre-chamber hospital care
D - No relief occurred

CHAMBER TREATMENT

60. CHAMBER TREATMENT FACILITY LOCATION

CITY ☐☐☐☐☐☐☐☐☐☐☐☐

STATE ☐☐ COUNTRY ☐☐☐☐☐☐☐☐☐☐☐☐

Date & Time of Treatment

MONTH/DAY/YEAR ☐☐/☐☐/☐☐ Time __________ AM PM

Name of hyperbaric facility:

☐☐☐☐☐☐☐☐☐☐☐☐

Treating doctor

☐☐☐☐☐☐☐☐☐☐☐☐

Form Completed By

____

61. TYPE OF CHAMBER
(please check)

Initial Treatment	Retreatment Chamber
☐ Monoplace	☐ Monoplace
☐ Dualplace	☐ Dualplace
☐ Multiplace	☐ Multiplace
☐ No chamber treatment given	

62. TOTAL DELAY FROM SYMPTOM ONSET TO RECOMPRESSION

HOURS (Up to 72) ☐☐ DAYS ☐☐

63. INITIAL TREATMENT

☐ A - USN TT4
B - USN TT5
C - USN TT6
D - USN TT6A
E - HART Protocol
F - KINDWALL Protocol
G - 45 fsw 90 min
H - 33 fsw 120 min
I - Other

____
____

64. TABLE EXTENSIONS REQUIRED?

☐ Y - Yes
N - No

65. RELIEF AFTER INITIAL TREATMENT?

☐ A - Complete
B - Partial
C - Temporary
D - None

66. IF PARTIAL OR TEMPORARY RELIEF, WHICH SYMPTOMS FROM #51?

(Please check):

1st ☐
2nd ☐
3rd ☐
4th ☐
5th ☐
6th ☐

67. RETREATMENT GIVEN
(Provide up to 3 responses)

TABLE	NUMBER OF TREATMENTS
☐	☐☐
☐	☐☐
☐	☐☐

A - USN TT4
B - USN TT5
C - USN TT6
D - USN TT6A
E - HART Protocol
F - KINDWALL Protocol
G - 45 fsw 90 min
H - 33 fsw 120 min
I - Other

____

68. RELIEF AFTER HYPERBARIC THERAPY COMPLETED?

☐ A - Complete
B - Partial
C - Temporary
D - Hyperbaric therapy not completed
E - None

69. RESIDUAL SYMPTOMS AFTER HYPERBARIC THERAPY COMPLETED?

☐ A - Pain only
B - Neurologic
C - Hyperbaric therapy not completed
D - None

70. DURATION OF RESIDUAL SYMPTOMS

(Circle one)

☐☐ DAYS
WEEKS
MONTHS

71. FINAL DIAGNOSIS:

☐ A - DCS I
B - DCS II
C - Air Embolism
D - Pulmonary Barotrauma
O - Other:

____
____
____

British Sub-Aqua Club
Incident/Accident Report Form

Organising Club/Branch			
Location			
Date	Time	Temperature	Weather
Water/Sea conditions		Max. Depth	Bottom
Tide/Wind	Surface Visibility	Underwater Visibility	
Purpose of dive			
Safety cover and safety precautions			

Diver directly involved

NAME	MEMBERSHIP NO.	AGE	DIVING QUALIFICATIONS
Physical condition, recently and on day of incident. Indicate any physical incapacity.			
Club/Branch			

Equipment. Indicate type, model and condition before and after dive.
Also amount of air in cylinders and weight on belt before and after dive.

	BEFORE DIVE:	AFTER DIVE:
Mask		
Fins		
Snorkel		
Life Jacket		
Weight belt		
Protective clothing		
Cylinders		
Demand Valve		
Harness		
Instruments		

In the event of decompression having been carried out list stops made at:

First Dive	10m	5m	Total ascent time
Second Dive	10m	5m	Total ascent time
Particulars of any dives in the previous 24 hours.			

British Sub-Aqua Club
Incident/Accident Report Form

Details of incident and any action taken: (Use another sheet of paper if this space is too small).

Please submit reports by diver's partner(s), dive leader, dive marshal and any other witnesses together with a summary of the incident leading to the accident. Copies of statements given to the police or other authorities should also be included. Please enclose any press cuttings, inquest report etc.

Report submitted by:	
Name	
Address	
Date	

UNDERWATER ACCIDENT REPORT

Forward report to:
NATIONAL UNDERWATER ACCIDENT DATA CENTER
P.O. Box 68 — Kingston, R. I. 02881

VICTIM INFORMATION

Name of Victim: .... (Last / First / Middle)

Address: ....

.... State ....

Victim's Sex ..... Age ..... Hgt. ...... Wgt. ......

Marital Status: M .... S .... D .... W ... UNK ...

Occupation ....

Employer ....

LOCATION OF ACCIDENT

Location of Accident (use landmarks, distance from prominent terrain features. Attach Chart or Map if available) .... State ....

CIRCLE LOCATION
(By Code Number)

1. Ocean, Bay, Sea
2. Minor Lake, Pond, Slough
3. Quarry, Pit, Open Mine
3A. Cave
4. River
5. Major Lake, Pond
6. Swimming Pool
7. Great Lakes

TIME AND PLACE OF ACCIDENT

Date and Time of Accident .... (Day Mo. Yr. Use 24-Hr. Clock)

Date and Time of Death ....

Date and Time of Recovery ....

Death Occurred in Water? .... (Yes or No)

Autopsy Performed: .... (Yes or No)

Cause of Death: ....

Medical Examiner .... (Name)

....

.... (Address / Phone)

CODE FOR NON-FATAL INCIDENT
Circle one only (A, B, C, or D) which best describes seriousness of incident. Important: Report all "incidents", however minor. Describe in detail on page 4. Include equipment factors.

A. Incapacitating injury rendering person unable to perform normal activities as walking or diving or to leave scene without assistance.
B. Nonincapacitating evident injury as loss of blood, abrasions, lump on head, etc.
C. Possible injury indicated by complaining of pain, blackout, limping, nausea, etc.
D. Incident with no apparent injury, (near miss, etc.)

DESCRIPTION OF DIVES AND ACTIVITIES

Description of all dives within previous 12 hours including accident dive.

Depth	Time Down	Surface Interval
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

Type of Diving: (Explain if Necessary)

Scuba ...... Skin ...... Other ..... Unknown .....

Others in accident .... (Yes or No)

Separate report filed .... (Yes or No)

At time of incident, Activities engaged in:

- Recreational .....
- Commercial .....
- Under instruction .....
- Instructing .....
- Cave diving .....
- Spear fishing .....
- Photography .....
- Night diving .....

At time of incident, Buddy record:

- Diving alone .....
- Diving with buddy .....
- Buddy distance .....
- Diving with more than one .....
- Distance to next nearest diver .....

Vessels involved .... (Yes or No)

U.S. Coast Guard aid sought .... (Yes or No)

(Give Details in "Description of Accident", Name, Captain, Address, Phone, etc.)

WITNESSES

Name	*Address*	*Phone*	*Function/Role*
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

Reported by:

Name ....

Address ....

City .... Phone ....

Other Contacts:

Name ....

Address ....

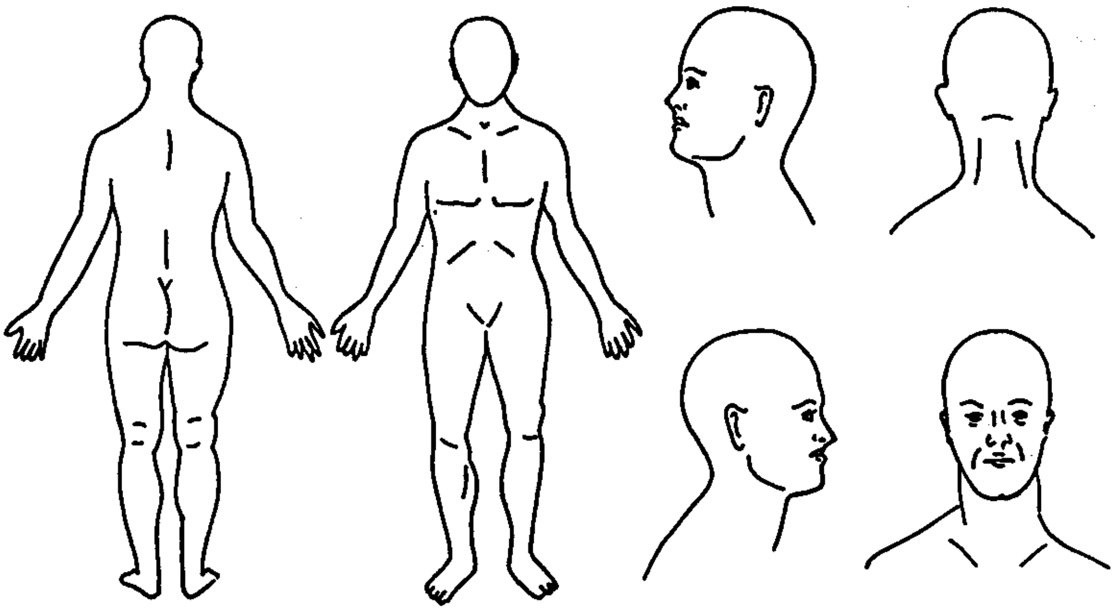
City .... Phone ....

ENVIRONMENTAL CONDITIONS	
Sea: Calm .... Moderate .... Rough	Weather: Clear .. Cloudy .. Fog .. Snow .. Rain ..
Current: Slight .. Moderate .. Strong .. Direction ...	Thunderstorm .. Tornado, Hurricane Other
Wave Height: ... Water Depth: ... Type Bottom: ...	Wind Force .... Direction ....
Water Temperature: (°F)	Air Temperature: (°F) ....

VISIBLE INJURIES

Illustrate all visible injuries (cuts, abrasions, fractures, etc.)

....
....
....



EXPERIENCE DATA

	Courses and Agency	
Swimming Experience: Years		
Skindiving Experience: Years	(1)	Certification Date ....
Scuba Experience: Years	(2)	-DO- ....
	(3)	-DO- ....

HUMAN FACTORS

Hours of sleep in past 24 hours ....

Time of last meal .... What and how much? ....

Time of last alcoholic drink .... What and how much? ....

Any known physical ailments, disability or impairment? ....

....

EQUIPMENT DATA

NOTE: *Equipment Brand, Type and Serial Number data need be included only if malfunction or failure was contributory to the incident.*

Equipment Data Date and Time of Inspection	Brand, Type	Present Before Diving (Yes or No)	Present at Time of Recovery (Yes or No)	Condition	Equipment	Brand, Type, Serial No.	Present Before Diving (Yes or No)	Present at Time of Recovery (Yes or No)	Condition
Diving Suit					Knife (Posit.)				
Hood					Ab Iron				
Boots or Socks					Flashlight				
Gloves or Mits					Depth Gauge				
Mask					Spear Gun				
Snorkel					Compass				
Fins					Regulator				
Weight Belt (lbs.)					Tank				
Buckle					Reserve				
Flotation Device					Watch				
Other Equipment									

Flotation Device: Used .... (Yes or No)

Tested after event? .... (Yes or No)

Regulator Tested? .... (Yes or No)

Results ....

Tank: Air Left .... (PSIG) **MFG.** .... **Date** ....

Last Hydro-Test Date ....

Last Visual Inspection Date ....

Internal Condition: Clean ....

Slight Corrosion ....

Extensive Corrosion ....

By: .... NAME ADDRESS PHONE

Special Comments on Equipment ....

Equipment Inspected by: .... NAME ADDRESS PHONE

Equipment: Released to/or Held by: .... NAME ADDRESS PHONE

DETAILED DESCRIPTION OF ACCIDENT

Describe in detail how the accident happened, including what the person was doing, any specific marine life or objects and the action or movement which led to the event. Include details of first aid or resuscitation efforts. Describe any "Decompression" and/or "Recompression-Treatment" in description of accident.

APPENDIX 7. CMAS QUALIFICATION EQUIVALENTS

June - Juin - Junio 1989

List of countries which have obtained CMAS equivalences

La liste des pays ayant obtenu les equivalences CMAS

Lista de los paises que han obtenido las equivalencias CMAS

Key to CMAS equivalences:

	(in English)	(in French)	(in Spanish)
a.	1-Star Diver	Plongeur 1 Etoile	Buceador 1 Estrella
b.	2-Star Diver	Plongeur 2 Etoiles	Buceador 2 Estrellas
c.	3-Star Diver	Plongeur 3 Etoiles	Buceador 3 Estrellas
d.	4-Star Diver	Plongeur 4 Etoiles	Buceador 4 Estrellas
e.	1-Star Instructor	Moniteur 1 Etoile	Instructor 1 Estrella
f.	2-Star Instructor	Moniteur 2 Etoiles	Instructor 2 Estrellas
g.	3-Star Instructor	Moniteur 3 Etoiles	Instructor 3 Estrellas

<u>Australia - Australie : Australian Underwater Federation</u>

NQS Scuba Diver	- b	NAC Level I (Assistant Instructor)	- e
NQS Advanced Diver	- c	NAC Level II (Scuba Instructor)	- f
NQS Advanced Divemaster	- d	NAC Level III (Advanced Divemaster Instructor)	- g

<u>Austria - Autriche : Tauchsportverband Osterreichs</u>

TSVÖ Grundstufe/1 Stern	- a	Tauchlehrer 1 Stern	- e
TSVÖ 2 Stern	- b	Tauchlehrer 2 Stern	- f
TSVÖ 3 Stern	- c	Tauchlehrer 3 Stern	- g

<u>Belgium - Belgique - Bélgica : Fédération Belge de Recherches et d'Activités Sous-Marines</u>

Brevet Elémentaire	- a	Aide Moniteur	- e
Brevet Moyen	- b	Moniteur Fédéral	- f
Brevet Supérieur	- c	Moniteur National	- g

Brazil - Brésil - Brasil : Confederacão Brasileira de Pesca e Desportos Subacuaticos

Plongeur 1 Etoile CBPDS	= a	Moniteur 1 Etoile CBPDS	= e
Plongeur 2 Etoiles CBPDS	= b	Moniteur 2 Etoiles CBPDS	= f
Plongeur 3 Etoiles CBPDS	= c	Moniteur 3 Etoiles CBPDS	= g

Bulgaria - Bulgarie : Fédération Bulgare des Sports Sous-Marins

Scaphandrier Plongeur Autonome	= a

Canada : Fédération Québécoise des Activités Subaquatiques

Plongeur 1 Etoile FQAS	= a	Moniteur 1 Etoile FQAS	= e
Plongeur 2 Etoiles FQAS	= b	Moniteur 2 Etoiles FQAS	= f
Plongeur 3 Etoiles FQAS	= c	Moniteur 3 Etoiles FQAS	= g

Colombia - Colombie : Federación Colombiana de Actividades Subacuáticas

Buzo Deportivo 1 Estrella	= a	Instructor I	= e
Buzo Deportivo 2 Estrellas	= b	Instructor II	= f
Buzo Deportivo 3 Estrellas	= c	Instructor III	= g

Cuba : Federación Cubana de Actividades Subacuáticas

Buzo 1 Estrella	= a	Instructor 1 Estrella	= e
Buzo 2 Estrellas	= b	Instructor 2 Estrellas	= f
Buzo 3 Estrellas	= c	Instructor 3 Estrellas	= g

Cyprus - Chypre - Chipre : Cyprus Federation of Underwater Activities

3rd-Grade Diver	= a	4th-Grade Diving Instructor	= e
2nd-Grade Diver	= b	3rd-Grade Diving Instructor	= f
1st-Grade Diver	= c	2nd-Grade Diving Instructor	= g
		1st-Grade Diving Instructor	= g

Czechoslovakia - Tchécoslovaquie - Checoslovaquia : Svaz potapecu Ceskoslovenska (Czechoslovak Divers' Association)

Insigne de Bronze	= a	Moniteur 3ème Classe	= e
Insigne d'Argent	= b	Moniteur 2ème Classe	= f
Insigne d'Or	= c	Moniteur 1ère Classe	= g

Denmark - Danemark - Dinamarca : Dansk Sportdykker Forbund

1-Star Diver	= a	1-Star Instructor	= e
Plongeur Sportif Nordique	= b	2-Star Instructor	= f
Plongeur de 1ère Classe	= c	3-Star Instructor	= g

Egypt - Egypte - Egipto : Egyptian Underwater Sports Federation

1-Star Diver	= a	1-Star Instructor	= e
2-Star Diver	= b	2-Star Instructor	= f
3-Star Diver	= c	3-Star Instructor	= g

Finland - Finlande - Finlandia : Suomen Urheilusukeltajain Liitto Ry

1-Star Diver	= a	1-Star Instructor	= e
Plongeur Sportif Nordique	= b	2-Star Instructor	= f
Plongeur de 1ère Classe	= c	3-Star Instructor	= g

France - Francia : Fédération Française d'Etudes et de Sports Sous-Marins

Brevet Elémentaire	= a	2ème Echelon + Initiateur	= e
1er Echelon	= b	Moniteur Fédéral 1er Degré	= f
2ème Echelon	= c	Bees 1er Degré/Auxiliaire	= f
Plongeur Autonome	= c	Moniteur Fédéral 2ème Degré	= g
		Bees 2ème Degré/National	= g

Germany, Federal Republic of - Allemagne (RFA) - Alemania (RFA) : Verband Deutscher Sporttaucher

Brevet Sporttauchen	= a	Tauchlehrer 1 Stern	= e
Brevet Bronze	= b	Tauchlehrer 2 Stern	= f
Brevet Silver	= c	Tauchlehrer 3 Stern	= g
Brevet Gold	= d		

Greece - Grèce - Grecia : Fédération Hellénique de la Pêche Sportive et des Activités Subaquatiques

Plongeur Autonome 1 Etoile	= a	Moniteur 1 Etoile	= e
Plongeur Autonome 2 Etoiles	= b	Moniteur 2 Etoiles	= f
Plongeur Autonome 3 Etoiles	= c	Moniteur 3 Etoiles	= g

Hong Kong : Hong Kong Underwater Federation

3rd-Class Diver (Pool)	= a	Club Instructor	= e
3rd-Class Diver	= b	Advanced Instructor	= f
2nd-Class Diver	= c	National Instructor	= g
1st-Class Diver	= d		

Indonesia - Indonésie : Indonesian Subaquatic Sport Association

Scuba Diver III	= a	Club Instructor II	= e
Scuba Diver II	= b	Club Instructor I	= f
Master Scuba Diver	= c	Regional Instructor	= g

Ireland - Irlande - Irlanda : Irish Underwater Council

Trainee Diver	= a	1-Star Instructor	= e
Club Diver	= b	2-Star Instructor	= f
Leading Diver	= c	3-Star Instructor	= g

Israel : Federation for Underwater Activities in Israel

2-Star Diver	= b	1-Star Instructor	= e
3-Star Diver	= c	2-Star Instructor	= f
		3-Star Instructor	= g

Italy - Italie - Italia : Federazione Italiana della Pesca Sportiva e Attività Subacquee

Plongeur 1er Degré	= a	Instructeur d'Immersion 1er Degré	= e
Plongeur 2ème Degré	= b	Instructeur d'Immersion 2ème Degré	= f
Plongeur 3ème Degré	= c	Instructeur d'Immersion 3ème Degré	= g

Japan - Japon : Fédération Japonaise des Activités Subaquatiques

1-Star Diver	= a	1-Star Instructor	= e
2-Star Diver	= b	2-Star Instructor	= f
3-Star Diver	= c	3-Star Instructor	= g

Korea, Republic of - Corée - Corea : Korea Underwater Association

Scuba Diver	= a	Instructor	= f
Advanced Scuba Diver	= b	Instructor Trainer	= g
Divemaster	= c		

Liechtenstein : Liechtensteiner Tauchsport Verband

Brevet 1 Etoile	= a
Brevet 2 Etoiles	= b

Luxembourg - Luxemburgo : Fédération Luxembourgeoise des Activités Subaquatiques

Plongeur 1er Degré	= a	Moniteur 1er Degré	= e
Plongeur 2ème Degré	= b	Moniteur 2ème Degré	= f
Plongeur 3ème Degré	= c	Moniteur 3ème Degré	= g

Malta - Malte : Federation of Underwater Activities in Malta

Elementary Grade	= a	1-Star Instructor	= e
Intermediate Grade	= b	2-Star Instructor	= f
Advanced Grade	= c	3-Star Instructor	= g

Mauritius - Ile Maurice - Isla Mauricio : The Mauritius Underwater Group

Novice Diver	= a	Club Instructor	= e
Sport Diver	= b	Advanced Instructor	= f
Dive Leader	= b	National Instructor	= g
Advanced Diver	= c		
1st-Class Diver	= d		

Mexico - Mexique : Federación Mexicana de Actividades Subacuáticas

Buceador Juvenil	= a	Assistant Instructor	= e
Buceador	= b	Monitor	= f
Buceador de Primera	= c	Instructor	= g

Monaco : Club de Chasse et d'Exploration Sous-Marine

Plongeur 1 Etoile	= a
Plongeur 2 Etoiles	= b
Plongeur 3 Etoiles	= c

Netherlands - Pays-Bas - Países Bajos : Nederlandse Onderwatersport Bond

1-Star Diver	= a	1-Star Instructor	= e
2-Star Diver	= b	2-Star Instructor	= f
3-Star Diver	= c	3-Star Instructor	= g

New Zealand - Nouvelle-Zélande - Nueva Zelandia : CMAS Dive Club

Dive Club 1-Star Diver	= a	Dive Club 1-Star Instructor	= e
Dive Club 2-Star Diver	= b	Dive Club 2-Star Instructor	= f
Dive Club 3-Star Diver	= c	Dive Club 3-Star Instructor	= g

Norway - Norvège - Noruega : Norges Dykkeforbund

1-Star Diver	= a	1-Star Instructor	= e
Plongeur Sportif Nordique	= b	2-Star Instructor	= f
Plongeur de 1ère Classe	= c	3-Star Instructor	= g

Poland - Pologne - Polonia : Polskie Towarzystwo Turystyczno Krajoznawcze

Brevet Inférieur	= a	Moniteur de Club	= e
Brevet Moyen	= b	Moniteur Régional	= f
Brevet Supérieur	= c	Moniteur National	= g

Portugal : Federación Portuguesa de Actividades Subacuáticas

Plongeur Niveau 1 FPAS	= a	Moniteur Niveau 1 FPAS	= e
Plongeur Niveau 2 FPAS	= b	Moniteur Niveau 2 FPAS	= f
Plongeur Niveau 3 FPAS	= c	Moniteur Niveau 3 FPAS	= g

San Marino - San Marin - San Marino : Federazione Sammarinese Attività Subacquee

FSAS Sommozzatore I Grado	= a	FSAS Istructtore I Grado	= e
FSAS Sommazzatore II Grado	= b	FSAS Istructtore II Grado	= f
FSAS Sommazzatore III Grado	= c	FSAS Istructtore III Grado	= g

Senegal - Sénégal : Fédération Sénégalaise des Activités Subaquatiques

Brevet Elémentaire Sénégalais	= a
Brevet 1er Echelon Sénégalais	= b
Brevet 2ème Echelon Sénégalais	= c

Singapore - Singapour - Singapur : Singapore Underwater Federation

SUF Openwater Diver	= a	SUF Instructor	= f
SUF Advanced Openwater Diver	= b	SUF National Instructor	= g
SUF Divemaster	= c		

South Africa - Afrique du Sud - Africa del Sur : South African Underwater Union

3rd-Class Diver	= b	Club Instructor plus 3-Star Sports Diver	= e
2nd-Class Diver	= c	Provincial Instructor plus 3-Star Sports Diver	= f
1st-Class Diver	= d	National Instructor	= g

Spain - Espagne - España : Federacion Española de Actividades Subacuáticas

Buceador Deportivo de 2° Clase	= b	Monitor Deportivo	= f
Buceador Deportivo de 1° Clase	= c	Instructor Deportivo	= g

Sweden - Suède - Suecia : Svenska Sportdykarförbundet

1-Star Diver	= a	1-Star Instructor	= e
Plongeur Sportif Nordique	= b	2-Star Instructor	= f
Plongeur de 1ère Classe	= c	3-Star Instructor	= g

Switzerland - Suisse - Suiza : Fédération Suisse des Sports Subaquatiques

Brevet Elémentaire	= a	Moniteur 1 Etoile	= e
Brevet 1er Echelon	= b	Moniteur 2 Etoiles	= f
Brevet 2ème Echelon	= c	Moniteur 3 Etoiles	= g

Tunisia - Tunisie - Túnez : Fédération Tunisienne des Sports Nautiques

Brevet de Plongeur 1er Degré	= a	Brevet de Moniteur 1er Degré	= e
Brevet de Plongeur 2ème Degré	= b	Brevet de Moniteur 2ème Degré	= f
Brevet de Plongeur 3ème Degré	= c	Brevet de Moniteur 3ème Degré	= g

United Kingdom - Royaume-Uni - Reino Unido : British Sub-Aqua Club

Novice Diver	= a	Club Instructor	= e
Sport Diver	= b	Advanced Instructor	= f
Dive Leader	= b	National Instructor	= g
Advanced Diver	= c		
1st-Class Diver	= d		

United States of America - Etats Unis d'Amérique - Estados Unidos : National YMCA Scuba Program

Bronze-Star Diver	= a	Scuba Teaching Assistant	= e
Silver-Star Diver	= b	Assistant Instructor	= f
Gold-Star Diver	= c	Scuba Instructor	= g

Venezuela : Federación Venezolana de Actividades Submarinas

Buceador Basico	= b	Instructor 1 Estrella	= e
Buceador Avanzado	= c	Instructor 2 Estrellas	= f
		Instructor 3 Estrellas	= g

Yugoslavia - Yougoslavie : Savez za Povodne Aktivnosti i sportski Ribolov na Moru SFR Jugoslavije

Plongeur 1 Etoile	= a	Moniteur 1 Etoile	= e
Plongeur 2 Etoiles	= b	Moniteur 2 Etoiles	= f
Plongeur 3 Etoiles	= c	Moniteur 3 Etoiles	= g

Zimbabwe : Zimbabwe Underwater Divers' Association

3-Star Diver	= b
2-Star Diver	= c

APPENDIX 8. ADDRESSES OF SCIENTIFIC DIVING ASSOCIATIONS

Note: The following addresses refer to organizations which are exclusively devoted to the pursuit of scientific research using diving. They are professional societies or associations whose membership is drawn from research laboratories and universities. The list does not include biomedical research into diving physiology. Many national sports diving federations have scientific committees, usually involving professional scientists, which exist to encourage fieldwork by volunteers and students. Such committees are not listed in this Appendix. The addresses of national diving federations can be obtained from the CMAS Year Book, published by CMAS, 47 rue du Commerce, Paris 75015, France.

American Academy of Underwater Sciences, 947 Newhall Street, Costa Mesa, California 92627, USA.

Australian Underwater Federation, AUF. P.O. Box 1006 Civic Square, Canberra, ACT 2608, Australia.

Barologia, South African Society for Underwater Science, c/o National Research Institute for Oceanology, P.O. Box 320, Stellenbosch 7600, South Africa.

Canadian Association of Underwater Sciences, c/o Neal Pollock, UBC Diving Operations, Suite 50 - 2075 Wesbrook Mall, University of British Columbia, Vancouver, BC, Canada V6T 1W5.

Centre Universitaire International de Plongée Scientifique, c/o Professeur Gaston Fredj, Department of Biological Oceanography, University of Nice, 28 Avenue de Valrose, 06034 Nice Cedex, France.

CMAS Scientific Committee. 47 rue du Commerce, Paris 75015, France.

Colimpha, c/o Alain Couté, Laboratoire de Cryptogamie, 12 rue de Buffon, Paris 75005, France.

Comitato Italiano Ricerche Studi Subacquei, c/o Victor de Sanctis, Via Bellaria 50, Pistoia, Italy.

Swedish Sportsdiving Federation, Idrottens Hse, S-12387 Farsta, Sweden.

Underwater Association for Scientific Research, c/o Dr. Richard Pagett, Wimpol Ltd., Hargreaves Road, Groundwell Industrial Estate, Swindon, Wiltshire, SN2 5AZ, UK.

APPENDIX 9. MEDICAL FORMS AND WAIVER FORMS

This Appendix uses the medical guidelines of the AAUS, CAUS and UASR to set down a suggestion for two levels of medical certification for diving: Class II and Class I. This format of two different levels has a basis in current practice at some institutions, but is not widely formalized at present. Generally the requirements of the Class II would be less stringent than those of the Class I. For example, the fitness requirement for a Class II would be a time/distance snorkel swim of 800 meters in 16 minutes using mask, fins, snorkel and an ABLJ, or alternatively a Master's Step Test. For a Class I a similar snorkel swim would be required, but would be supplemented with a sub-maximal stress test on a bicycle ergometer or treadmill with a three-lead electrocardiogram.

These examples of tests would be appropriate for the Class II. A somewhat more stringent series of tests would be required for the Class I and would be supplemented with a standard oxygen tolerance test and a long bone X-ray series. The duration of validity of the Class II would be 12 calendar months, and of the Class I, 6 calendar months.

It may well be that the current basic or Class II standard will remain adequate for the bulk of scientific diving.

A check-sheet should be developed based on the medical guidelines noted.

EXAMPLE 1

THE UNIVERSITY OF BRITISH COLUMBIA

Occupational Health and Safety
Old Administration Building
6328 Memorial Road
Vancouver, B.C. Canada V6T 2B3

Telephone (604) 228-4218

Dear Doctor:

Re:____

This person will be diving (S.C.U.B.A.) under the auspices of the The University of British Columbia. The University requires a medical examination as part of the medical standards, prior to beginning diving activities, and on a periodic basis.

Kindly note the evaluation requirements detailed on the accompanying information sheet and medical history and examination form. Please return the medical history and examination form to me when it is completed.

Thank you for your assistance.

THE UNIVERSITY OF BRITISH COLUMBIA
Diving Safety Program

INFORMATION SHEET FOR MEDICAL EXAMINERS

Tests for Medical Authorization for Diving

Test	Initial Examination	Subsequent Examination
Visual Acuity	x	x
Color Blindness	x	
Hearing	x	x
Fitness Evaluation	x	x
ECG	(a)	(b)
Urinanalysis	x	x
Chest X-ray	x	(b)
Hematocrit or Hemoglobin	x	x
Sickle Cell Index	(b)	
White Cell Count	x	x

(a) over 40 years of age or if clinically indicated
(b) only if clinically indicated

1. Clarification of Tests

A. Ophthalmology. Standard visual acuity and color blindness tests shall be given. Personnel with uncorrected vision greater than 20/80 shall require corrective lenses.

B. E.N.T. An extensive E.N.T. examination shall be given and shall include observed movement of the drum during Valsalva manuever. Hearing shall be 'conversationally adequate'.

C. Fitness. A fitness evaluation shall be conducted by the UBC Diving Officer and the results entered on the Physical Examination Form (Item 18). Minimum requirements are that divers be able to swim 800 m in 16 minutes with mask, fins, snorkel, and buoyancy device. A Master's Step Test may be used as an alternate method of evaluation (step up onto chair 5 times in 5 seconds; pulse should return to pre-exercise level in 45 seconds).

D. ECG. A standard 12 lead ECG shall be given to individuals over 40 years of age or if clinically indicated.

E. Urology. A standard urinanalysis shall be performed for all personnel.

F. Hematology. Standard hematocrit or hemoglobin and white cell count shall be performed for all divers. A sickle cell index shall be performed upon initial examination for divers of known negroid descent.

G. Radiology. A full inspiration, posterior chest x-ray shall be done on initial examination of all divers and when clinically indicated.

H. Additional Tests. The tests in this list are minimum tests for University Medical Authorization for Diving. Additional tests shall be done at the University Diving Medical Officer's or examining physician's discretion.

2. Disqualifying and Limiting Factors for Diving

The following factors shall disqualify personnel from diving or limit their exposure to diving depending on severity, presence of residual effects, response to therapy, number of occurrences, and diving mode. In all cases, final responsibility and authority for medically authorizing personnel to engage in diving activity shall rest with the University Diving Medical Officer.

System	Disqualifying Factors	Allowable Factors
General	Gross obesity Impaired exercise tolerance.	(See 1C.)
E.N.T.	Perforated eardrums. Chronic otitis media or mastoid operation. Chronic destruction of sinuses or eustachian tubes. Inability to clear ears.	Healed perforations. Successful tympanoplasty. Unilateral nasal block. Sinusitis if not adversely affected by diving, but not if of infective origin.
Oral Cavity	Oral disease. Bad teeth and fillings.	Dentures should extend to mucobuccal fold and should be retained in place in all jaw positions. Partial plates should generally be retained during diving.
Respiratory	Any chronic lung disease, past or present. Any recent history of bronchial asthma requiring treatment. Emotionally-induced asthma. History of pneumothorax.	Mild chronic bronchitis (smoker?) without emphysema or important airways obstruction if exercise tolerance, spirometry, and CXR normal. Healed primary focus tuberculous scars in established divers or trainees. Bronchial asthma, if clinically normal between attacks and exercise tolerance normal.
Cardio-Vascular	Heart disease. Hypertension. Systolic BP over 150 mm Hg. Diastolic BP over 90 mm Hg. (100 mm Hg if aged over 35)	Minor asymptomatic heart disease other than ischaemic with specialist referral and approval. Varicose veins (if severe, caution must be observed using dry suit).

System	Disqualifying Factors	Allowable Factors
Abdomen G.U.S.	Proteinuria until cause established. Gross abnormalities of renal tract. Pregnancy.	Peptic ulcer, unless unduly active or troublesome. Abdominal hernias (advise repair).
Limbs	Disease, amputation or deformity excessively limiting ability to swim. Juxta-articular osteonecrosis.	Arthritis or arthrodesis not markedly limiting ability to swim or rescue others.
Endocrine	Insulin-requiring diabetes.	
Central Nervous System	Severe stammering. Epilepsy, including post-traumatic fits. Cranial surgery. Any serious head injury in the past two years or head injury with sequelae.	Must present an acceptable EEG.
Hematology	Hemoglobinopathies.	
Additional	Malignancies (active). Impaired organ function caused by alcohol or drug use. Conditions requiring continuous medication for control. Vestibular end organ destruction.	Malignancies treated and without recurrence for five years.

THE UNIVERSITY OF BRITISH COLUMBIA
Diving Programme
MEDICAL HISTORY AND EXAMINATION FORM
(this side to be completed by applicant)

Name______________________________ Age_____ Sex_____ Date____________
Address____ Phone____________
MSP______________________________ Family Physician____________________

1. Have you had previous experience in diving? Yes_____ No _____
2. When driving through mountains or flying do you have trouble equalizing pressure in your ears or sinuses? Yes_____ No _____
3. Have you ever been rejected for service, employment, or insurance for medical reasons? (if yes, explain under "Remarks" or discuss with doctor) Yes_____ No _____
4. When was your last physical examination? Date__________ Results______________
5. When was your last chest X-ray? Date__________ Results______________
6. Have you had an electrocardiogram? Date__________ Results______________
7. Have you had an electroencephalogram? Date__________ Results______________
8. Do you smoke? Yes_____ No _____ If so, how much ______________

(Check the blank if you have, or ever had, any of the following. Explain under "Remarks" or discuss with doctor.)

9. ___ Frequent colds or sore throat.
10. ___ Hay fever or sinus trouble.
11. ___ Trouble breathing through nose (other than during colds).
12. ___ Painful or running ear, mastoid trouble, broken eardrum.
13. ___ Hard of hearing.
14. ___ Asthma or bronchitis.
15. ___ Shortness of breath after moderate exercise.
16. ___ Pleurisy.
17. ___ Collapsed lung (pneumothorax)
18. ___ Chest pain or persistent cough.
19. ___ Tire easily.
20. ___ Spells of fast, irregular, or pounding heartbeat.
21. ___ High or low blood pressure.
22. ___ Any kind of "heart trouble".
23. ___ Frequent upset stomach, heartburn or indigestion, peptic ulcer.
24. ___ Frequent diarrhea or blood in stool.
25. ___ Anemia or (females) heavy menstruation
26. ___ Belly or backache lasting more than a day or two.
27. ___ Kidney or bladder disease; blood, sugar or albumin in urine.
28. ___ Broken bone, serious sprain or strain, dislocated joint.
29. ___ Rheumatism, arthritis, or other joint trouble.
30. ___ Severe or frequent headaches.
31. ___ Head injury causing unconsciousness.
32. ___ Dizzy spells, fainting spells or fits.
33. ___ Trouble sleeping, frequent nightmares or sleepwalking.
34. ___ Nervous breakdown or periods of marked nervousness or depression.
35. ___ A phobia for closed-in spaces, large open places, or high places.
36. ___ Any neurological or psychological conditions.
37. ___ Train, sea or air sickness, nausea.
38. ___ Alcoholism or any drug or narcotic habit (including regular use of sleeping pills, benzedrine, etc.)
39. ___ Recent gain or loss of weight or appetite.
40. ___ Jaundice or hepatitis.
41. ___ Tuberculosis.
42. ___ Diabetes
43. ___ Rheumatic fever
44. ___ Dental bridgework or plates.
45. ___ Susceptibilty to panic.
46. ___ Pain from altitude or flying.
47. ___ Surgery.
48. ___ Any serious accident, injury or illness not mentioned above (describe under "Remarks", give dates).
49. ___ In what sports or exercise do you regularly engage: ______________

REMARKS: ____

PHYSICAL EXAMINATION FORM
(this side to be completed by medical staff)

A. Nursing Station:

Height __________ (ins.) Weight __________ (lbs.)
Blood Pressure__________ Pulse __________

Vision:	Right Eye	Left Eye
Uncorrected	________	________
Corrected	________	________
Color vision	________	________

B. Medical History:

Is there a significant past history which would disqualify the applicant from diving?
Yes_____ No______

Remarks:____

____

C. Examination: (please check the following items; if abnormal, give details below)

		Normal	Abnor.
1.	General appearance (including obesity, gross defects, postural abnormalities).............	______	______
2.	Head and neck..............	______	______
3.	Eyes......................	______	______
4.	Nose and sinuses...........	______	______
5.	Ears (including hearing, otitis, perforation).......	______	______
6.	Mouth and throat...........	______	______
7.	Spine......................	______	______
8.	Lungs and chest............	______	______
9.	Heart......................	______	______
10.	Abdomen....................	______	______

		Normal	Abnor.
11.	Inguinal rings (males)....	______	______
12.	Genitalia (males).........	______	______
13.	Anus and rectum (if indicated)................	______	______
14.	Extremities...............	______	______
15.	Skin (eruptions or reactions)................	______	______
16.	Neurologic................	______	______
17.	Psychiatric (including apparent motivation for diving, emotional stability claustrophobia).	______	______
18.	Fitness...................	______	______

______________________ ________
Diving Officer Signature Date

Explanation of abnormalities: ____

____

____

D. Test Results (See Information Sheet for Medical Examiners)

Chest X-Ray ____________ Hemoglobin/Hematocrit______ Urinanlysis ____________
12 lead ECG ____________ WBC ____________________ Sickel cell screen ________

E. Final Impression: (circle one)

Approval: I find no defects which I consider incompatible with diving.

Conditional Approval: I do not consider diving in this person's best interest, but find no defects which present marked risk. I have discussed my impression with him/her.

Disapproval: This applicant has defects which in my opinion clearly would constitute unacceptable hazards to his/her health and safety in diving.

Signature of examining physician__________________________ Date______________

The University of British Columbia
Interdepartmental Memorandum

Date : ______________________

To : ______________________ **Phone:** ______________

From : Neal Pollock, Diving Officer
Occupational Health and Safety
228-2990

****

Subject : UNIVERSITY DIVING REGISTRATION STATUS

<u>The University diving records presently show:</u>

Certification: Diver-in-Training / Certified Scientific Diver / Instructor / Assistant Instructor

	Current? Yes	Current? No
Project description and approval form: ______		
Depth certification: 10 - 20 - 30 - 40 meters: ______		
Special endorsements or limitations: ______		
Date of last logged dive: ______		
Number of dives last 6 months: ______		
Number of dives last 12 months: ______		
Date of last medical: ______		
Date of last open water check-out: ______		
Date of last diver rescue training: ______		
Date of last CPR certification: ______		
______		
______		

If any of the above are listed as "no record" or as "not current", you are no longer authorized to dive under University auspices. Please discontinue your diving activities and contact me at your earliest convenience so I can help you correct the discrepancy and get reinstated.

If the above are all listed as "current" and in-date, you remain authorized to dive under University auspices. Congratulations for the good work in keeping up your certification.

* NOTE: An asterisk before an item indicates that it will soon be out-of-date. If any appear on this page, please take appropriate action to renew before your certification is no longer current.

Memorandum for Medical Officers

The certification of a man to be fit to dive implies that he is both physically and psychologically healthy. A diver may have to undergo physical strain under adverse conditions and upon his reaction to an emergency may depend not only his own life but also the lives of others. During the examination he should be carefully observed for psychological defects.

A certificate of fitness should not be given when a man is undergoing treatment for any acute condition.

Please record the results of your examination in SI units where applicable.

Please use a ball-point pen when filling in this form.

The following conditions disqualify a man from diving:

1. Most skin disorders. Saturation divers are particularly prone to intertrigo and otitis externa.
2. Excessive obesity.
3. Inability to clear the ears.
4. Perforated eardrum, chronic otitis or mastoid operation.
5. Chronic obstruction of the Eustachian tubes or sinuses.
6. Any chronic lung disease, past or present; bronchial asthma; history of pneumothorax.
7. Heart disease, essential hypertension.
8. Chronic gastro-intestinal disease (e.g. peptic ulcers).
9. Hernia.
10. Gross abnormality of the renal tract.
11. Epilepsy; severe head injury; cranial surgery; disease of the central nervous system.
12. Severe hearing or visual defects.
13. Diabetes.
14. Sickle cell trait.
15. Psychiatric disorder.
16. Severe stammering.

The Health and Safety Executive issue a document entitled: "Recommendations on Medical Examination of Divers: Information for Examining Doctors". Amongst other things this refers to long-bone and joint X-rays. These should be taken in accordance with the recommended techniques of the M.R.C. Decompression Sickness Panel. A copy of this document entitled "Radiological Skeletal Survey for Aseptic Necrosis of Bone in Divers and Compressed Air Workers: Recommended Technique" is available from the M.R.C. Decompression Sickness Central Registry, 21 Claremont Place, Newcastle upon Tyne, NE2 4AA.

Please send the yellow copies of completed forms, and the bone and joint X-ray films, to the Registry in Newcastle.

MEDICAL CERTIFICATE. CODE OF PRACTICE FOR SCIENTIFIC DIVING

Name :

Address :

Date of Birth :

Number of years diving :

PART 1. TO BE PUT TO THE CANDIDATE BY THE EXAMINING DOCTOR

Have you suffered at any time from any of the following ?
Answer YES or NO. If YES, give details in space at bottom of page.

1. Earache, or ear discharge ....
2. Sinus trouble, nose bleeds, hay fever ....
3. Any lung disease, bronchitis or asthma..........
4. Disease of the heart & circulation including high blood pressure ....
5. Fits, recurrent headaches or any nervous disorder..........
6. Blackouts or fainting attacks, concussion ....
7. Diabetes ....
8. Peptic ulcer; hernia, gastro-intestinal affections ....
9. Do you wear dentures ? ....
10. Do you smoke ?..........
11. Have you any physical disability or abnormality ? ....
12. Have you ever been admitted to hospital ? ....
    If YES, for what reason ? ....
13. Are you taking (or recently taken) any tablets or any other treatment ?..........
14. Any diving injury, including damaged ear drums, decompression sickness, etc ? ....
15. Date of last medical examination ....
16. Date of last Chest X-Ray ....

Details : ....

....

....

I declare the above answers to be true and that I have omitted nothing that might be relevant to my fitness for diving.

Signature : .... Date : ....

MEDICAL CERTIFICATE. CODE OF PRACTISE FOR SCIENTIFIC DIVING

PART 2. TO BE COMPLETED BY EXAMINING DOCTOR

Height: .... Weight: ....kg.

Ears: R Drum.................... Canal .... Valsalva ....

L Drum .... Canal .... Valsalva ....

Sinuses: ....

Teeth and gums: ....

Chest movements: .... Chest expansion (cm^3) ....

Lung Fields: ....

Heart sounds: ....

Pulse.................... Blood pressure.................... Apex beat....................

Abdomen: .... Hernial orifices....................

Central nervous system: ....

....

SPECIAL INVESTIGATIONS

1. Full Plate Chest X-Ray: ....
2. Exercise tolerance (See information note) ....
3. Urine: Sugar ....
   Albumen....................
   Blood ....
   Ketones ....
4. Peak Expiratory Flow: ....
   (if available)

If facilities allow the following are recommended in addition:

1. Exercise ECG (on first examination, annually thereafter if aged over 35 years)....................
2. FEV_1.................... FVC.................... FEV_1/FVC....................

REMARKS: ....

....

....

CERTIFICATE OF FITNESS

In my opinion the candidate is fit to carry out scientific or amateur diving activities.

Signature: .... Qualifications: .... Date: ....

Address: ....

MEDICAL CERTIFICATE. CODE OF PRACTICE FOR SCIENTIFIC DIVING INFORMATION FOR MEDICAL OFFICERS CONDUCTING EXAMINATIONS OF DIVERS

Particular attention should be paid to the ENT and Respiratory Systems. It must be borne in mind that diving may involve moderately severe exercise under adverse conditions. The safety of the candidate and others depends on his physical and psychological fitness.

System	Disqualifying Factors	Allowable Factors and Other Points
General	Gross obesity. Impaired, exercise tolerance.	(See note below).
E.N.T.	Perforated eardrums. Chronic otitis media or mastoid operation. Chronic destruction of sinuses or Eustachian tubes. Inability to clear ears.	Healed perforations. Successful tympanoplasty. Unilateral nasal block. Sinusitis if not adversely effected by diving but not if of infective origin). Valsalva test of drum mobility optional, and outweighed by practical diving test.
Oral Cavity	Dentures must be retained in place on fully opening the mouth and not be dislodged by placing jaws together in any position, or by movement of one denture against the other. They should extend to the muco-buccal fold. Applicants should be advised about bad teeth and fillings. No firm advice as to whether an individual should or should not wear his dentures when diving is possible, but small dentures should not be worn when diving.	
Respiratory	Any chronic lung disease, past or present (see opposite). Any recent history of bronchial asthma requiring treatment. History of pneumothorax. Emotionally-induced asthma (each case should be judged on its merits).	Mild chronic bronchitis (smoker?) without emphysema or important airways obstruction if exercise tolerance, spirometry and CXR normal. Healed primary focus tuberculous scars in established divers or new recruits. Bronchial asthma, if clinically normal between attacks, and exercise tolerance normal. Full-plate CXR required.
Cardio-vascular	Heart disease. Hypertension. Systolic B.P. over 150 mm Hg. Diastolic B.P. over 90 mm Hg. (100 mm Hg if aged over 35).	Minor asymptomatic heart disease other than ischaemic following specialist referral and approval. Varicose veins (but if severe, caution against use of dry suit).
Abdomen, G.U.S.	Proteinuria until cause established. Gross abnormalities of renal tract Pregnancy.	Peptic ulcer, unless unduly active or troublesome. Abdominal hernias (but advise repair).
Limbs	Disease, amputation or deformity excessively limiting ability to swim. (Specialist referral is advisable).	Arthritis or arthrodesis not markedly limiting ability to swim or rescue others.
Endocrine	Insulin-requiring diabetes.	
Central Nervous System	Severe stammering. Epilepsy, including post-traumatic fits. Cranial surgery. Any serious head injury in the past two years.	To be judged on merit. Must present an acceptable EEG.

Note: **Exercise Tolerance:** A candidate must not fail to pass the following simple test:
After stepping up onto a chair 5 times in 5 seconds, the pulse rate should return to the pre-exercise level in 45 seconds.

WOODS HOLE OCEANOGRAPHIC INSTITUTION

STATEMENT OF UNDERSTANDING

To be completed by all divers

1. Skin, Scuba and surface-supplied diving are physical activities involving heavy exertion. A diver must be in good general health, free from cardiovascular and respiratory disease, and have good exercise tolerance. Even momentary impairment of consciousness underwater may be fatal.
2. While swimming or using skin, Scuba or surface-supplied diving equipment, the body is subject to a variety of influences that may become potentially hazardous. Some of these hazards include, but are not limited to drowning, ruptured ear drums or sinuses, air embolism, decompression sickness (the 'bends'), and a variety of other barotrauma (pressure-related injuries).
3. There are organisms in the water that may bite, sting, scratch, claw, or inject substances into the body.
4. There are other water related problems that include, but are not limited to reduced visibility, rough water, strong currents, and cold temperature.
5. When diving from a boat a person may be subjected to bodily injury from carelessness due to activity, or related to equipment handling, or from just being present on a boat at sea.
6. The individual diver must realize that he/she is ultimately responsible for his/her own safety. It is clearly the diver's responsibility to refuse to dive if, in his/her judgement, conditions are unsafe.

Statement: I am in good physical and mental health and am free from cardiovascular, respiratory, or other diseases or ailments, which could endanger me while diving.

I hereby voluntarily exempt and release__________________________ and Woods Hole Oceanographic Institution, its Trustees, officers and employees, from liability for personal injury, property damage, or death, arising from diving instruction, diving activities or any activities incidental to diving operations.

Signed____ Date______________________
Candidate

Signed____ Date______________________
Diving Supervisor

AI.I.MH (MEDICAL HISTORY) TO BE FILLED IN BY CANDIDATE

1. SURNAME	OTHER NAMES	2. DATE OF BIRTH
3. ADDRESS	PHONE	4 SINGLE ☐ MARRIED ☐ 5. SEX MALE ☐ FEMALE ☐
6. NEXT OF KIN	ADDRESS	
7. PRINCIPAL OCCUPATION		
8. HAVE YOU ANY DISEASE OR DISABILITY AT PRESENT?	☐ NO ☐ YES	NAME OF CONDITION:
9. ARE YOU TAKING ANY TABLETS, MEDICINES OR OTHER DRUGS?	☐ NO ☐ YES	TYPE OF DRUG.

HAVE YOU EVER SUFFERED OR DO YOU NOW SUFFER FROM ANY OF THE FOLLOWING DISORDERS.

	NO	YES
10. RHEUMATIC FEVER		
11. SWOLLEN OR PAINFUL JOINTS		
12. ANY HEART DISEASE		
13. HIGH BLOOD PRESSURE		
14. ABNORMAL SHORTNESS OF BREATH		
15. BRONCHITIS OR PNEUMONIA		
16. PLEURISY OR SEVERE CHEST PAINS		
17. COUGHING UP BLOOD		
18. T B (CONSUMPTION)		
19. CHRONIC OR PERSISTENT COUGH		
20. PNEUMOTHORAX (COLLAPSED LUNG)		
21. ASTHMA OR WHEEZING		
22. ANY OTHER CHEST COMPLAINT OR CHEST INJURY OR OPERATION ON CHEST		
23. HAY FEVER		
24. SINUSITIS		
25. ANY OTHER NOSE OR THROAT TROUBLE		
26. DEAFNESS OR RINGING NOISES IN EAR		
27. DISCHARGING EARS OR OTHER INFECTION		
28. OPERATIONS ON EARS		
29. EYE OR VISUAL PROBLEMS		
30. WEAR GLASSES		
31. FAINTING, BLACKOUTS, FITS OR EPILEPSY		
32. SEVERE HEADACHES OR MIGRAINE		
33. SLEEPWALKING OR FREQUENT NIGHTMARES		
34. SEVERE DEPRESSION		
35. CLAUSTROPHOBIA		
36. ANY OTHER MENTAL ILLNESS		
37. KIDNEY OR BLADDER DISEASE		
38. DIABETES		
39. INDIGESTION OR PEPTIC ULCER		
40. VOMITING BLOOD OR RECTAL BLEEDING		
41. RECURRENT VOMITING OR DIARRHOEA		
42. JAUNDICE OR HEPATITIS		
43. MALARIA OR OTHER TROPICAL DISEASE		
44. VENEREAL DISEASE		
45. SEVERE LOSS OF WEIGHT		
46. HERNIA OR RUPTURE		
47. HAEMORRHOIDS (PILES)		
48. ANY SKIN DISEASE		
49. ANY REACTION TO DRUGS OR MEDICINES		
50. ANY OTHER ALLERGIES		
51. UNCONSCIOUSNESS		
52. CONCUSSION OR HEAD INJURY		
53. ANY MAJOR JOINT OR BACK INJURY		
54. ANY FRACTURES (BROKEN BONES)		
55. ANY PARALYSIS OR MUSCULAR WEAKNESS		
56. DENTURES		
57. MOTION SICKNESS (CAR, PLANE, SEA)		

NOTES ON HISTORY

MEDICAL HISTORY (CONT'D)

NOTES ON HISTORY

		NO	YES
58	DO YOU SMOKE		
59.	APPROX. NUMBER OF CIGARETTES A DAY		
60.	HAVE YOU EVER BEEN REJECTED FOR INSURANCE		
61.	HAVE YOU BEEN UNABLE TO WORK FOR MEDICAL REASONS		
62.	HAVE YOU EVER BEEN ON A PENSION		
63.	HAVE YOU ANY DISABILITY WHEN FLYING IN AIRCRAFT		
64.	HAVE YOU EVER LIVED WITH A PERSON WITH T B		
65.	HAS ANY MEMBER OF YOUR FAMILY HAD T B		
66.	OR ATTEMPTED SUICIDE		
67.	OR HAD MENTAL ILLNESS		
68.	OR FITS. EPILEPSY		
69.	HAVE YOU ANY INCAPACITY DURING PERIODS		
70.	ARE YOU NOW PREGNANT		
71.	HAVE YOU BEEN IN HOSPITAL OR A MENTAL INSTITUTE FOR ANY REASON		
72	HAVE YOU HAD ANY OPERATIONS		
73.	HAVE YOU ANY OTHER ILLNESS OR INJURY NOT MENTIONED IN THIS LIST		

} (FEMALES ONLY) [items 69–70]

A1.2. DMH (DIVING MEDICAL HISTORY) TO BE COMPLETED BY CANDIDATE

1.	APPROX DATE OF FIRST SNORKEL DIVE	
2.	APPROX. DATE OF FIRST COMPRESSED AIR (SCUBA) DIVE	
3.	APPROX. NUMBER OF COMPRESSED AIR DIVES SINCE	
4	GREATEST DEPTH OF ANY DIVE	
5.	LONGEST DURATION OF ANY DIVE	
6.	APPROX. DATE OF FIRST DIVE ON MIXED GASES (PRO DIVERS ONLY)	
7.	APPROX. NUMBER OF DIVES ON MIXED GASES (PRO DIVERS ONLY)	

HAVE YOU EVER SUFFERED, OR DO YOU NOW SUFFER FROM ANY OF THE FOLLOWING DISORDERS RELATED TO DIVING?

		NO	YES
8.	SEVERE EAR SQUEEZE		
9.	RUPTURE OF EARDRUM		
10.	DEAFNESS		
11.	GIDDINESS OR DIZZINESS		
12.	SEVERE SINUS SQUEEZE		
13.	SEVERE LUNG SQUEEZE		
14.	RUPTURED LUNG (BURST LUNG)		
15.	EMPHYSEMA		
16.	PNEUMOTHORAX		
17.	AIR EMBOLISM		
18.	NITROGEN NARCOSIS		
19.	DECOMPRESSION SICKNESS (BENDS)		
20.	NEAR DROWNING		
21.	SEVERE MARINE ANIMAL INJURY		
22.	OXYGEN TOXICITY		
23.	CARBON DIOXIDE TOXICITY		
24.	CARBON MONOXIDE TOXICITY		
25.	DYSBARIC OSTEONECROSIS (BONES)		
26	ANY OTHER DIVING INCIDENTS		

I CERTIFY THAT THE ABOVE INFORMATION IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE

A1.3.ME (MEDICAL EXAMINATION) TO BE COMPLETED BY MEDICAL PRACTITIONER

1. Physique Good Average Poor	2. Height cm ins	3. Weight kg lbs	4. Colour Eyes Hair Skin	5. Expansion Exp. cm ins Insp. cm ins Diff. cm ins
6. Vision R6/ Corr 6/ L6/ Corr 6/	7. Colour Perception	8. Urinalysis Albumen Glucose		9. Chest X-ray Date........................ Place........................ Result........................

10. Skeletal (Long Bone) X-ray Date ....Place .... Result.. (Pro divers only)	11. Respiratory Function Test Vital Capacity .... After .... $FEV_{1.0}$ .... Broncho .... Percentage .... Dilator ....

12. Audiometry

		Frequency Hz						
		250	500	1000	2000	4000	6000	8000
Air	Loss in dB (R)							
	Loss in dB (L)							
Bone	Loss in dB (R)							
	Loss in dB (L)							
REMARKS.								

CLINICAL EXAMINATION	Normal	Abnormal
13. HEAD, SCALP, FACE AND NECK		
14. NOSE, SEPTUM, AIRWAY		
15. SINUSES		
16. MOUTH, THROAT, TEETH, SPEECH		
17. EARS GENERAL		
18. TYMPANIC MEMBRANE		
19. EUSTACHIAN TUBE FUNCTION		
20. PUPILLARY REFLEXES		
21. EYE MOVEMENTS		
22. VISUAL FIELDS		
23. ABDOMEN AND G I TRACT		
24. ENDOCRINE SYSTEM		
25. LYMPHATIC SYSTEM		
26. POSTURE AND GAIT		
27. SPINE		
28. UPPER LIMBS		
29. LOWER LIMBS		
30. CRANIAL NERVES		
31. REFLEXES		
32. SENSATION		
33. CEREBELLAR FUNCTIONS		
34. EMOTIONAL STABILITY, PHOBIA		
35. MENTAL CAPACITY		
36. IDENTIFYING MARKS		
37. CHEST, LUNG FIELDS		
38. CARDIAC AUSCULTATION		
39. VASCULAR SYSTEM		
40. OPHTHALMOSCOPY		
41. EXERCISE CAPACITY		
42. ECG AT REST		
44. BLOOD PRESSURE		
45. PULSE RATE/MIN		
46. SHARPENED ROMBERG SCORE	SECS	

NOTES ON ABNORMALITIES

FIT TO DIVE
UNFIT TO DIVE
OTHER
REASONS:

SIGNED: DATE:

WOODS HOLE OCEANOGRAPHIC INSTITUTION

DIVING MEDICAL EXAMINATION

TO EXAMINING PHYSICIAN:

This person is an applicant for training or employment involving diving with self-contained underwater breathing apparatus (SCUBA) or surface-supplied equipment. Your opinion of the applicant's physical fitness is requested. A report form and completed medical questionnaire are enclosed. Since the information requested may be of importance in preventing or treating a diving accident, please be as specific as possible in detailing your results and comments. Please bear in mind that diving involves a number of unusual medical problems:

Diving may involve HEAVY EXERTION and IMMERSION IN COLD WATER. A diver must be in good general health, free from cardiovascular and respiratory disease, and have good exercise tolerance.

Diving involves significant changes in ambient pressure and gas volume. All body spaces must equalize pressure readily. Obstructive lung disease may cause catastrophic accidents on ascent.

Even momentary impairment of consciousness underwater may be fatal.

Responsibility to other divers is a consideration. Even if a diver were willing to take a calculated risk with his own safety, if an accident occurred, other divers would be at risk in attempting rescue. In addition, evidence of neurotic trends, recklessness, accident proneness, panicky behavior or questionable motivation should be evaluated.

ABSOLUTE CONTRAINDICATIONS TO DIVING (The following are examples of conditions which present unacceptable risks to health and safety while diving):

History of seizure disorder (except febrile convulsions in infancy)

Recurrent or unexplained syncope, whether neurogenic or cardiovascular

Insulin-dependent diabetes

Sickle cell disease

Meniere's disease

Active asthma if medication is required for control, if there have been attacks within the past two years, or if bronchospasm has ever been associated with exertion or inhalation of cold air

Ear surgery where prosthesis has been implanted in the conduction chain

History of spontaneous pneumothorax

Chronic inability to equalize pressure in middle ears or sinuses; unhealed perforation of tympanic membrane

Pulmonary cysts, blebs, bullae, or definite air trapping lesions detected by x-ray; significant obstructive pulmonary disease

History of coronary artery disease; myocardial infarction; arrythmias; ventricular septal defect

Chronic alcoholism or drug addiction

RELATIVE CONTRAINDICATIONS TO DIVING (The following are examples of conditions which may disqualify, limit, or restrict diving depending on severity, presence of residual effects, response to therapy, etc.):

Any condition requiring continuous medication for control (e.g., antihistamines, steroids, barbiturates, mood altering drugs, antihypertensive drugs)

Pregnancy

Decreased pulmonary reserve from any cause

Obesity

Malignancies, unless treated and without recurrence for five years

History of chest surgery; recent operations

TEMPORARY DISQUALIFICATIONS

Upper or lower respiratory infection or severe hay fever causing inability to equalize pressure in ears or sinuses, or causing chest congestion; middle ear infection

Inguinal hernia

Minor perforation of tympanic membrane

Alcohol or drug intoxication

Any medication which could interfere with normal diving

Divers often enter polluted water and are subject to injuries requiring antitetanus treatment. It is strongly advisable to maintain routine immunizations up-to-date.

If you feel the need for additional tests beyond those outlined in the attached form or for consultation, please contact the W.H.O.I. Diving Safety Officer or Institution Safety Officer. It may be in the Institution's best interest to discontinue the person's participation in diving activities.

For a more complete treatment of medical standards for diving, please refer to:

Davis, J.E., Kindwall, E.P., and Youngblood, D.A., "Selection of Divers: Examination and Physical Standards," in Hyperbaric & Undersea Medicine, J.E. Davis, ed., 1981, 1:3, pp. 2-7, Medical Seminars, Inc., 8480 Fredericksburg Road, #241, San Antonio, TX 78229.

Strauss, Richard H., ed., Diving Medicine, 1976, Grune & Stratton, NY, pp. 341-347.

Signs and symptoms of some diving accidents may mimic those of stroke or heart attack. The possibility of decompression sickness or gas embolism should be considered for any patient exhibiting neurological deficit (e.g., unconsciousness, paralysis, weakness, confusion, inability to control bowels or urine, chest pain, etc.) within minutes to hours after diving (as shallow as 4 feet). The National Diving Accident Network (D.A.N.), Duke University Medical Center, (919) 684-8111, may be called at any time for consultation regarding diagnosis, immediate care, transportation to a hyperbaric facility, and chamber location. Please retain the above number for your future reference.

Terrence M. Rioux, Diving Safety Officer

WOODS HOLE OCEANOGRAPHIC INSTITUTION

PHYSICIAN'S REPORT OF DIVING MEDICAL EXAMINATION

Applicant's Name__________________________ Physician's Phone ( )______

Physician's Name__________________________ Address__________________

(print, type, or stamp)

TYPE OF EXAMINATION:___INITIAL___ANNUAL___SPECIAL (MAJOR ILLNESS OR INJURY)

CLINICAL EVALUATION	NORMAL	ABNORMAL	RESULTS, COMMENTS (Please be Specific)
General Physical Condition			
Ears, Nose, Throat			
Chest X-Ray (initial, once/4 years)			
ECG (initial, annual age 40 & over)			
Visual Acuity			
Color Blindness (initial exam only)			
Hearing			
Hematocrit or Hemoglobin			
White Blood Cell Count			
Urinalysis			
Other as Determined by Examining Physician (please specify)			

The following conditions should be made known to any physician who may treat this person for a diving accident (include medical conditions, medication, allergies, etc.);

Opinion, disqualifications, limitations, temporary restrictions, comments:

______ APPROVED (I find no defects which I consider incompatible with diving)

______ CONDITIONAL APPROVAL (I do not consider diving to be in the applicant's best interests, but find no defects which present a marked risk. I have explained this to the applicant.)

______ DISAPPROVED (The applicant has defects which in my opinion would constitute unacceptable hazards to health & safety in diving. I have explained and discussed this with the applicant.)

Physician's Signature __________________________Date______________________

Applicant's Signature __________________________Date______________________

WOODS HOLE OCEANOGRAPHIC INSTITUTION

DIVING MEDICAL QUESTIONNAIRE & HEALTH HISTORY

INSTRUCTIONS: Please answer the following questions as accurately as possible. Be sure all blanks are filled in completely, sign and date, and return to the Diving Safety Officer. Incomplete forms will be returned and authorization to dive may be unnecessarily delayed.

NAME________________________AGE______OCCUPATION__________________

DEPARTMENT __________________ PROJECT NUMBER___________________________

HEIGHT ________________WEIGHT_____________

1. Have you had any previous experience in diving? Yes ____ No____
If so, have you ever had bends, embolism or an other pressure related injury? Yes _____ No _____
2. Have you had any difficulty equalizing pressure in your ears or sinuses? Yes____No____
3. What do you do for exercise? How often do you participate? (over)
4. Have you ever been rejected for service or employment for medical reasons? Yes _____No _____
5. Date of last physical examination ________Physician/Facility_______________
Address____
6. Date of last chest X-ray _______________EKG ____________________
7. Have you ever had an electrocardiogram? Yes ____No ____ Electroencephalogram? Yes _____No _____
8. Do you smoke? Yes ____No ____ How much? ____________
9. Have you ever had or do you now have: (Please check at left of each item)

Yes	No		Yes	No	
___	___	Frequent colds or sore throat	___	___	Hay fever or sinus trouble
___	___	Trouble breathing through nose	___	___	Painful, running ear, mastoid trouble
___	___	Ruptured eardrum			
___	___	Fast or irregular heartbeat	___	___	Chest pain, persistent cough
___	___	High or low blood pressure	___	___	Heart trouble
___	___	Frequent diarrhea, bloody stools	___	___	Persistent back or stomach ache
___	___	Kidney or bladder disease	___	___	Recent gain or loss of weight
___	___	Frequent upset stomach, heart burn, ulcers	___	___	Jaundice or hepatitis
			___	___	Rheumatic fever
___	___	Tuberculosis	___	___	Broken bone, serious sprain
___	___	Venereal disease	___	___	Severe or frequent headaches, migraines
___	___	Rheumatism, arthritis, joint trouble	___	___	Head injury causing unconsciousness
___	___	Insomnia, nightmares,sleepwalking	___	___	Nervous breakdown, depression
___	___	Dizziness, fainting, convulsions	___	___	Motion sickness
___	___	Alcohol, drug, narcotic habit	___	___	Claustrophobia
___	___	Adverse reaction to serum, drug or medicine	___	___	Any neurological condition
			___	___	Diabetes
___	___	Any serious illness not mentioned above	___	___	Cancer

Please explain on next page.

REMARKS. Briefly describe any items checked YES. List all medications currently used and allergies you may have.

APPENDIX 10. SCIENTIFIC DIVER BREVET APPLICATION FORMS

Application number: ....

CONFÉDÉRATION MONDIALE DES ACTIVITÉS SUBAQUATIQUES
WORLD CONFEDERATION OF UNDERWATER ACTIVITIES

SCIENTIFIC COMMITTEE

President
N.C. Flemming, UK.
Vice-President,
A. Bachrach, USA.
Secretary,
L-A. Rundblad, Sweden.

CMAS Head Office
34 Rue du Colisée
75008, Paris, France.

Note: Application may be made on a photocopy of this form.

APPLICATION FORM FOR CMAS SCIENTIFIC DIVER BREVET

PART I. TO BE COMPLETED BY THE APPLICANT

1. NAME OF APPLICANT (Please Print) ....
2. ADDRESS OF APPLICANT (Please Print) ....
....
....
Country ....

3. STATEMENT OF DIVING TRAINING

Please complete . A *or* both of the following sections A and B:

A. I.. (name) certify that I am in possession of CMAS 3-star diver certificate number .... issued to me in may name by the national diving federation or organisation of .... (country). The name of the national diving federation or organisation which issued my certificate is .... (name of federation or organisation).

B. I.. (name) certify that I am in possession of government approved training certificate number .... see section 5A for full details of my training.

Note. Delete section . . B if not applicable.

4. STATEMENT OF SCIENTIFIC AFFILIATION

Please complete one *or* both of the following sections A and B:

A. I certify that I am a member of the national Scientific Diving Association of................................ (country). The name of the national Scientific Diving Association is .... (See PART II).

B. I certify that I am a lecturer/teacher/research worker/technician/research student/student* at the following establishment of learning or research: ....
.... (name and address of establishment). I certify that I use diving in my studies or research, and this is permitted by the establishment. (See PART III).

Notes. Delete section A or B if not applicable.
* Delete words not applicable.

5. STATEMENT OF LEGAL STATUS

Please complete *one* of the following sections:

A. In .... (country), which is the country where I hold my diving qualifications and where I conduct my studies and/or research, I have the legal status of a diver who dives at work. The government of .... (country) requires scientific divers at work to possess government-approved diving training and a government-approved certificate permitting them to dive at work. I certify that I hold government-approved diving training certificate number ...., issued on .... (date), at .... (place of issue), and that I am legally permitted to dive as a scientific diver at work in .... (country). A copy of my certificate is attached.

B. In .... (country), which is the country where I hold my diving qualifications and where I conduct my studies and/or research, there is no law which requires scientific divers who dive in the course of their work to hold a government-approved certificate of training. In .... (country) sports diving qualifications are legally sufficient to qualify me to dive in the course of scientific work.

Note. Delete the paragraph not applicable.

6. **DECLARATION**

I declare that all the statements above are true to the best of my knowledge on this date. I understand that the CMAS Scientific Diver Certificate does not entitle me to be employed as a commercial or industrial diver.

Signed .... (Applicant)

Date ....

IMPORTANT: PART I MUST BE COMPLETED AND SIGNED BY THE APPLICANT BEFORE PARTS II OR III ARE SIGNED BY THE SUPPORTING ASSOCIATION OR ESTABLISHMENT.

COMPLETE PART II OR PART III OR BOTH

PART II. TO BE COMPLETED BY THE SUPPORTING SCIENTIFIC DIVING ASSOCIATION

7. To be completed by the Chairman, President, or Secretary of the national Scientific Diving Association cited in section 4A above.

Name and Address of Association (Please Print) ....

....

.... Country: ....

8. I certify that .... (name of applicant, please print) is a member of .... (name of Scientific Diving Association).

9. I have read Part I of this form completed and signed by the applicant.

Signed .... (Chairman/President/Secretary).

Date ....

PART III. TO BE COMPLETED BY THE SUPPORTING ESTABLISHMENT OF LEARNING OR RESEARCH

10. To be completed by the Head of Department of the establishment cited in section 4B above.

Name and address of the establishment where the applicant works or is a student: ....

....

.... Country: ....

11. I certify that .... (name of applicant, please print) is a lecturer/teacher/research worker/research student/technician/student* at this establishment.

Note. * Delete words not applicable.

12. I have read Part I of this form completed and signed by the applicant.

Signed .... (Head of Department)

Date ....

Department Stamp: ....

13. The completed form, together with supporting signatures in Parts II or III, and the copy of the official government-approved certificate (if referred to in paragraph 5A) should be posted to the following address; together with payment by cheque of 80 French Francs or an International Money Order for 80 French Francs (payable to CMAS).

CMAS
Scientific Diver Brevet,
34 Rue du Colisée,
75008
PARIS
FRANCE

APPENDIX 11. EXTENDED LOCAL RULES

Statutory legislation concerning diving safety sometimes requires that an employer or institute publish a set of rules or internal regulations, stating their standards and methods for maintaining safety. It can be time-consuming and unnecessary for numerous laboratories and institutes to write separate rules starting from first principles; the resulting variability may even be dangerous and prevent movement of divers between laboratories. It may therefore be preferable for universities, institutes, or laboratories to publish a statement of policy that the Unesco/CMAS Code of Practice will apply to diving carried out by their employees and students, supplemented by such manuals or standards as may be suitable to cover the detailed conditions of equipment and environment required by national legislation. This will ensure maximum compatibility.

From time to time it may then be necessary for the employing institution to publish extensions or variations of the rules, but maintaining the continuity of statutory authority. Such extensions of the rules could cover matters such as diving on weekends when a recompression chamber was not manned, diving in exceptionally dangerous locations such as in a tidal race, or near reefs and headlands, or diving in shipping lanes, etc. Such local rules would be completely specific to a given diving area or establishment. The following formula is suggested:

NAME OF INSTITUTE EMPLOYING SCIENTIFIC DIVERS ....

LOCAL DIVING RULES, NOTICE NUMBER....................DATE ....

WHEREAS the*

....

requires every Employer of Scientific Divers to produce or publish a set of Diving Rules, the contents of which shall be consistent with the legislation,

AND WHEREAS The Unesco/CMAS Code of Practice for Scientific Diving is applied in this institution/university/laboratory/establishment and is part of the agreed Diving Rules, together with the following documents:

.... (Codes of Practice or Standards)

.... (Manuals and Training Standards)

THE FOLLOWING EXTENSION OF THE RULES IS HEREBY BROUGHT TO THE ATTENTION OF DIVERS:

....

....

* Title of national

legislation requiring employers   Signed...........................

to publish safety rules.

Diving Officer/Diving Control Board

APPENDIX 12. SAMPLE DIVE RECORD SHEETS

This Appendix contains examples of daily and monthly dive record forms, and institutional records.

*University of British Columbia

Monthly Log

Monthly logs must be completed and turned in to the Diving Operations Office at the end of each month of diving. Record all open water dives including recreational dives. Divers must log a minimum of 12 dives per year to remain certified. Additionally at least one dive must be made to the depth of certification every six months to retain certification at that depth.

Directions for Filling Out Log

Location - give the accepted name (e.g., The Cut, Whytecliff Park) or a brief description (e.g., Wall at Orlebar Point) or chart coordinates.

Scientific Discipline - specify the scientific purpose(s) of the dive using the following categories:

Biology	(BI)	Oceanography	(OC)
Chemistry	(CH)	Other: Specify	
Geology	(GE)		
Archaeology	(AR)		

Mission - specify the mission(s) of the dive using the following categories:

Observation/Recording	(OR)	Installation/Maintenance	(IM)
Surveying	(SU)	Photography	(PH)
Collection/Sampling	(CS)	Recreation	(RE)
Coring	(CO)	Training	(TR)
		Other: Specify	

Dive Buddy(ies) - give the name(s) of your buddy(ies).

Depth Group - put a check mark in the appropriate box to indicate the depth group (in meters) of the maximum depth of the dive (e.g., maximum depth 55 feet - check box for 20 meters).

Dive Time - give time underwater for scuba or umbilical (surface supply) dives; time in water for snorkel dives. Time should be in hours and minutes (e.g., 0:55).

Mode - specify the principal diving mode of the dive using the following categories:

Scuba-Air	(SA)	Snorkel	(SN)
Umbilical-Air	(UA)	Other: Specify	

Additional Information - list any additional information that is pertinent to the record of the dive using the following categories:

Night	(NI)	Zero-Visibility	(ZV)
Ice	(IC)	Contaminated Water	(CW)
Current	(CU)	Enclosed Spaces	(ES)
Altitude	(AL)	Blue-Water	(BW)
Decompression	(DE)	- specify bottom time and depth for decompression schedule used.	
Incident Report Filed	(IR)	Other: Specify	

None - if there is no additional information enter "NONE".

Signature - ensure you have filled out the entire form including your name, the month, and the date of your last medical, then sign and date the form at the bottom and send it to:

University Diving Operations Office
Auditorium Annex, 1924 West Mall
Vancouver, B.C. V6T 1W9

WARNING: If the form is incomplete or unreadable it will be returned for corrections.

Monthly Dive Log - UBC Diving Operations Office

Name ______________ Month ______________ Date of Last Medical ______________

	DATE Dy/Mo/Yr	LOCATION Name, Description or Chart Coord's	SCIENTIFIC DISCIPLINE	MISSION	DIVE BUDDY(IES)	DEPTH GROUP (Meters)					DIVE TIME	MODE	ADDITIONAL INFORMATION
						10	20	30	40	40+			
1.													
2.													
3.													
4.													
5.													
6.													
7.													
8.													
9.													
10.													
11.													
12.													
13.													
14.													
15.													
16.													
17.													
18.													
19.													
20.													

The information above accurately summarizes my diving activity.

Signature ______________ Date ______________

DIVE INFORMATION (Dive No.)

Name/address of Contractor: ....

....

Date: ....

Site Location(s): ....

....

Name(s) of Diving Supervisor(s): ....

Equipment used: SCUBA ..../Surface Demand/Other (state) ....

Breathing mixture used: Compressed Air: ..../Other: (state) ....

Task: (including tools) ....

....

	Dive 1	Dive 2	Dive 3	Dive 4	Dive 5
Time of leaving surface:	....	......	....	....	......
Time of leaving bottom:	....	......	....	....	......
Bottom Time (mins):	....	......	....	....	......
Time of arrival at surface:	....	......	....	....	......
Maximum Depth (m):	....	......	....	....	......
Stops at ....(depth). Time:	....	......	....	....	......
Stops at ....(depth). Time:	....	......	....	....	......

Decompression implemented? No/Yes

RNPL/BS-AC: .... USN: ..../Other: ....

Any decompression sickness?: Yes/No

Any other illness/discomfort/injury?: Yes/No

Any adverse health and safety factors?: Yes/No

Action/comments (if "yes"):

....

....

....

Signed: Diver .... Supervisor ....

ALL THE INFORMATION ABOVE IS REQUIRED BY LAW AND MUST BE COMPLETED FOR EACH DIVE OR GROUP OF DIVES

ADDITIONAL NOTES:

Name(s) of diving companion(s): ....

....

WATER: Visibility (m) ...... *Temp (C)* ......

Current (kt) ...... *Tide* ...... *Swell* ......

WEATHER: Temp (C) ...... *Wind* ...... *Cloud* ......

Visibility ...... *Precipitation* ......

Comments:

SCIENTIFIC OBSERVATIONS

DIVE RECORDS

Dive No.........

Name and address of University, Institute, School, Museum, etc.

....

Dive Date ....Geographical Location ....

Vessel/Structure/Platform ....

Marshall/Supervisor........................Dive Companion Dive 1 ....

Equipment used ....Dive Companion Dive 2 ....

....Dive Companion Dive 3 ....

Surface line attendant Dive 1................. Dive 2.................. Dive 3..................

STOPS

	Leave Surface	Arrive Bottom	Leave Bottom	Arrive 10m	Leave 10m	Arrive 5m	Leave 5m	Arrive Surface	Max Depth	Bottom Time	Total Time
DIVE ONE											
DIVE TWO											
DIVE THREE											

Decompression Tables used ....

Brief work description...

....

Any decompression sickness or other illness or adverse effects

....

Defects of equipment..

....

Adverse environmental factors ....

Diver's Signature..

On-site Dive Marshall's Signature ....

Chief Diver's Signature...

ADDITIONAL INFORMATION Project name or number......................................

Chief Scientist..

Water Conditions: Depth to Bottom..........................Surface Temp...................

Bottom Temp .... Current............................ Tide ....

Visibility..Waves/Sea State..

Weather Conditions: Air Temp................................ Cloud...............................

Wind............................ Fog .... Precipitation ....

Institute or Department Diving Officer or Chief Diver observations for Diving Operations Log Book, including arrangements for emergency support.

....

....

Signature ....Date ....

Scientific or Archaeological Observations

Dive No ....

APPENDIX 13. SCIENTIFIC DIVER TRAINING STANDARDS AND CERTIFICATION

Training and certification can be carried out within sports diving clubs affiliated to national or international bodies, military organizations or within institutions that maintain diving programmes. Commonly national scientific diving organizations will recognize some level of training and/or experience as a sufficient basic training standard.

Certification can be made by the national or international body or through a recognized institute that maintains training and certification programmes. In most cases, certificates will have some national level of significance. In the opinion of the Editors, it is not necessary to have a single set of certification standards, so long as there is good agreement between the certifying authorities as to levels of training and competency necessary at the different levels.

Two levels of scientific diver certification may be the simplest approach: 'diver-in-training' and certified Scientific Diver. The 'diver-in-training' requirements would essentially be those for an entry level diver (NAUI Level II, CMAS 2-Star) and restrictions would be placed on the respective diver's activities (i.e. maximum depth 20 meters, supervised directly by a certified Scientific Diver). It is not intended that divers would be required to dive to certain depths each month to maintain this standard for scientific diving, but they might be required to do so for institutional or other certificate requirements.

The certified Scientific Diver requirements would be those equivalent to an advanced sports diver level (NAUI Level IV, CMAS 3-Star) with the certification of the Diving Officer, and there will be no direct restrictions placed on the diver's activities other than those indicated by the Diving Officer. However, a cautionary note would indicate the need for advanced training when undertaking diving in extreme conditions or when using equipment other than self-contained air-breathing apparatus.

Examples of a statement of understanding between the institute and the diver, an application form for training, and an institution temporary permit for visiting investigators are supplied.

DIVING TRAINING/CERTIFICATION

STATEMENT OF UNDERSTANDING

To be completed by candidates for diver training

STANDARD: All areas of evaluation of this course are based on the question, "Will this person make a safe and reliable diver?"

EVALUATION: You will be required to learn and demonstrate to the satisfaction of the diving supervisor, through written/oral examination(s) and physical performance, the following:

1) Applied Sciences: physics, physiology and medical aspects as they relate to a diver's performance in the water.
2) Diving Equipment: a basic knowledge of the purposes, features, types and use of skin and SCUBA diving equipment.
3) Diving Safety: a basic knowledge and skill level of lifesaving and first aid as applied to diving.
4) Diving Environment: a basic knowledge of the physical and biological aspects, with particular emphasis of the New England region, and including regulations, dangers, water movement and characteristics, and conservation.
5) Safe Diving Skills: competent knowledge and performance of skin and SCUBA pre-and-post diving, surface, and underwater skills.

Your attitude during the course will affect your individual scores and final status.

CERTIFICATION: You are not assured of certification to dive for Woods Hole Oceanographic Institution merely by attending the course, or even by completing or passing all of the areas of evaluation. The Diving Safety Officer will make a subjective decision at the end of the course, based on your total performance and attitude. Possible classifications are as follows:

1) Provisional Permit.
2) Certification to depth level based upon prior training and experience, as well as performance and attitude.
3) Placement in another class for further training.
4) Rejection for diving certification.

RESPONSIBILITIES: You will have several responsibilities during the course. These will include:

1) Your responsibility for your own safety and the safety of others around you.
2) Your individual responsiblity to Woods Hole Oceanographic Institution for damages or missing items.
3) Your responsibility for your own equipment and personal effects.

Signed ______________________________ Date ________________
Candidate

Signed ______________________________ Date ________________
Diving Safety Officer

WOODS HOLE OCEANOGRAPHIC INSTITUTION

APPLICATION FOR SCUBA DIVING TRAINING/CERTIFICATION

Instructions: SCUBA diving training/certification is available for approved W.H.O.I. affiliated individuals who need to use the technique to further their research at the Institution or for support activities related to Institution business. Requirements for eligibility and procedures for application may be found in the W.H.O.I. Diving Safety Manual.

Please fill in the requested information as completely as possible. Print legibly or type. Incomplete, missing or late application forms or supporting documentation may result in unnecessary delays or in rejection for training. Attach the requested enclosures and return to the Diving Locker.

PERSONAL INFORMATION: Name____________________ Date of Birth__________
Job Title or Major__________________________ Department______________
Office/Lab Location ______________Ext.______ Home Phone______________
Mailing Address ____

DESCRIPTION OF NEED FOR DIVING TRAINING/CERTIFICATION: Briefly describe project for which you will use diving at the Institution. Temporary Permit Applicants include location and dates of cruise/operation ______________________________________

____

____

____

TRAINING: SCUBA Courses Completed

_____ I have never completed a SCUBA course. _____ I have completed the following courses:

Course Title or Level	Agency (NAUI, PADI YMCA, etc.)	Location	Total Hours			Date of Completion.	Instructor's Name & #
			Lecture	Pool	Open Water		

CPR, First Aid, Lifesaving, Swimming, W.S.I., Boating, etc.

EXPERIENCE: Total Career Open Water SCUBA Dives___ Total Hours Underwater___ Maximum Depth (Career)___ Maximum Depth (Last Year)____ Dives Past Year____ Date of Last Open Water Dive___/___/____Have You Ever Dived for W.H.O.I.?____ Date Certified___/___/___ Date Left___/___/___Swimming Experience: Non-swimmer__ Swimmer__ Years Year Last Swam___Snorkeling Experience:______ Nonsnorkeler_____ Years Year Last Snorkeled __________

Brief resume of any commercial, military, or scientific diving experience. Include names of supervisors, companies/universities/units for which you worked, dates of affiliation, and duties. Include all diving related skills not noted above:

____

____

____

Indicate with the appropriate letter if you have ever had experience diving in the following situations: E Extensive(more than 20 times) L Limited(1-4 times) M Moderate (5-20 times); leave blank if inexperienced

___Diving from boats/ships
  ___Small boats (up to 20' length)
  ___Vessels from 21' to 100'
  ___Ships (over 100')
___Shore diving
  ___Rocks or 'ironshore'
  ___Surf
___Penetration w/o direct access to surface
  ___Ice diving
  ___Cave diving
  ___Wreck diving
___Night diving
___Decompression diving
___Diving at sea ('blue water')
___Diving EMT or chamber operator
___Cold water (below 45?F)
___Turbid water (0-5' visibility)
___Very clear water (50' visibility)
___Diving in salt water
___Diving in fresh water
  ___Ponds, lakes, quarries
  ___Rivers
___Mud or silty bottom
___Kelp 'forest'
___Coral reef
___Currents (1/2 knot and over)
___Altitude diving (over 2,000' elev.)
___Use of variable volume dry suits
___Commercial diving
___Surface-supplied equipment
___Saturation or mixed gas

ENCLOSURES: Enclose the following supporting documents with this application:

1) Physical Examination Report. Must have been signed within the past year, marked "Approved for Diving," and signed by a licensed physician.
2) Copies of all pertinent certification cards (front and reverse).
3) A dive log must be presented for inspection (certified divers only).

STATEMENT: I certify that the above information is correct and that I am in good health. I agree to follow the safety regulations of the W.H.O.I. Diving Safety Manual and to abide by whatever limitation or restriction may be imposed by the Diving Safety Officer.

______________________________ ______________
Signature of Candidate Date

APPROVAL: The following persons must endorse the candidate's participation in the W.H.O.I. diving program before training or certification can commence:

Project Supervisor ______________________ ______________________ ____________
Name (printed or typed) Signature Date
Department Chairman______________________ ______________________ ____________
Diving Safety Officer______________________ ______________________ ____________
Diving Board Chairman______________________ ______________________ ____________

--DO NOT WRITE BELOW LINE--

TRAINING/CERTIFICATION PROCEDURE ASSIGNED:
____Basic/Refresher Course ____Class Convening Date ____________
____Experienced Diver Evaluation ____Reciprocal Cert. From Approved University/Institution Diving Program
____Temporary Diving Permit. Expiration Date ____Commencement Date __________ ____Rejection

REMARKS: Please attach to this form.

WOODS HOLE OCEANOGRAPHIC INSTITUTION

TEMPORARY SCUBA DIVING PERMIT FOR VISITING INVESTIGATORS

Diving at W.H.O.I. is subject to rules and regulations which are outlined in the Woods Hole Oceanographic Institution Diving Safety Manual. Persons who are planning to dive for a W.H.O.I.-sponsored project or cruise, or who plan to use W.H.O.I. facilities (e.g., ships, stations, piers, equipment) for diving operations, must be certified to do so by the Institution Diving Safety Officer.

Authorized visitors may apply for a Temporary Diving Permit. This permit is restricted to participation in the specific diving operation/cruise for which requested, and is subject to such other restrictions (e.g., depth, diving buddy, type of activity or environment, etc.) as the Diving Safety Officer may impose. Temporary permits must be renewed for each project/cruise by persons not affiliated with W.H.O.I.

W.H.O.I. employees and students, or visitors who desire regular Institution certification, must comply with the normal procedures as outlined in the W.H.O.I. Diving Safety Manual. Because of time constraints, Temporary Permit candidates may have portions of the procedures waived or simplified; however, in the interest of safety, certain minimal requirements must be met. The Diving Safety Officer may impose other requirements in addition to the following at his discretion:

HEALTH: The visiting diver must provide documentation of having passed a physical examination for diving within one year of the termination of the diving operation. As a minimum, the examination form should include a statement that the candidate is medically qualified for diving, the signature of the examining physician, the physician's name, address and phone (printed or typed), and a statement describing any condition extant or medication currently taken which could affect or restrict the candidate's ability to dive safely. The W.H.O.I. medical form is available on request.

TRAINING: A certification card from a nationally recognized diver training agency (e.g., NAUI, PADI, YMCA, NASDS, SSI) must be submitted. A Xerox (front and back) copy will suffice.

EXPERIENCE: A log recording at least 12 career open water dives, with at least 8 having been accomplished within the past year must be submitted. If a visitor is affiliated with a university or institution with a formal diving program (i.e., with a diving control board and a diving safety manual), a letter from the Diving Safety Officer certifying that the candidate is currently qualified and conforms to the above requirements may suffice.

Please fill in the requested information on the reverse of this form, attach the necessary documentation, and send as a package to the Principal Investigator for whom you will be working at W.H.O.I. Visitors who have participated in W.H.O.I. sponsored diving operations within the past year may already have some of the above documentation on file with the Institution Diving Safety Officer. However, it is the visitor's responsibility to ensure that all requirements are up to date and submitted with sufficient lead time to be processed.

Terrence M. Rioux

Diving Safety Officer

APPLICATION FOR TEMPORARY W.H.O.I. DIVING PERMIT

INSTRUCTIONS: Fill in the requested information as completely as possible. Print legibly or type. Incomplete, missing or late forms or documentation may result in unnecessary delays or rejection.

PERSONAL INFORMATION:

Name______________________________ Age_____ Sex____
Occupation or Major____
Work/UniversityAddress____

TRAINING:	Course or Level	Title (NAUI, etc)	Agency	Location	Date of Completion	Instructor's Name
CPR						
1st Aid						
Diving						
Courses						

EXPERIENCE: Total Career SCUBA Dives_________ Total Hours Underwater______ Maximum Depth (Career)__ Maximum Depth (Last Year)__ No. Dives Past Year__ Have you ever dived for W.H.O.I.? ________When? (month, year)____________

Indicate with the appropriate letter if you have ever had experience diving in the following situations: E Extensive (more than 20 times); L Limited (1-4 times); M Moderate (5-20 times); leave blank if inexperienced.

___Diving from boats/ships
  ___Small boats (up to 20' length)
  ___Vessels from 21' to 100'
  ___Ships (over 100')
___Shore diving
  ___Rocks or 'ironshore'
  ___Surf
___Penetration w/o direct access to surface
___Ice diving
___Cave diving
___Wreck diving
___Night diving
___Decompression diving
___Diving at sea ('blue water')
___Diving EMT or chamber operator

___Cold water (below 45?F)
___Turbid water (0-5' visibility)
___Very clear water (50' visibility)
___Diving in salt water
___Diving in fresh water
  ___Ponds, lakes, quarries
  ___Rivers
___Mud or silty bottom
___Kelp 'forest'
___Coral reef
___Currents (1/2 knot and over)
___Altitude diving (over 2,000' elevation)
___Use of variable volume dry suits, Unisuit, etc.
___Commercial diving
___Surface-supplied equipment
___Saturation or mixed gas

CRUISE/DIVING OPERATION INFORMATION: Brief description of the diving operation
____
____
Principal Investigator for whom you will be working at W.H.O.I.:______________
Location of diving operation:______________________________________
Date(s) of diving operation:_______________________________________
I certify that the above information is correct and that I am in good health. I agree to follow the safety regulations of the W.H.O.I. Diving Safety Manual and to abide by whatever limitation or restriction may be imposed by cognizant W.H.O.I. Diving authorities, including the Diving Safety Officer.

____________________ __________
Signature of Candidate Date

APPENDIX 14. GLOSSARY OF SELECTED TERMS AND DEFINITIONS

This glossary is not a complete glossary of diving terms, but is a list of some terms and acronyms used in this code. A complete glossary of American diving terminology has been published by the Best Publishing Company, Post Office Box 1978, San Pedro, California 90723, USA. Terms are also usually defined with legal precision in the preamble to government legislation, but the meanings may vary slightly from document to document and from country to country.

AAUS: American Academy of Underwater Sciences.

AB: Adjustable Buoyancy.

ABLJ: Adjustable buoyancy life jacket (vest, compensator). A life jacket which supports the diver safely on the surface with his/her face above water, and can be inflated using a hand controlled valve while submerged, using air either from direct feed, or from a separate cylinder.

ATA or ATM: Atmospheres Absolute. Air pressure at sea level at 0 degrees Centigrade temperature is defined at about 14.7 lbs/in^2 and is called Standard Atmospheric Pressure, 1 ATA = 10.07 meters sea water, 33.05 feet sea water, 33.93 feet freshwater, 1.033 kg/cm^2, 14.696 lbs/in^2, 760 mm Hg, or 1.013 bars

BIBS: Built-In Breathing System.

Boyle's Law: Boyle's Law defines the relationship between pressure and volume. It states that at a constant temperature, the volume of a given mass of gas will vary inversely with the absolute pressure, or $P_1V_1 = P_2V_2$.

BSAC: British Sub Aqua Club.

CAUS: Canadian Association for Underwater Sciences.

Cd: Cadmium.

Charles' Law: Charles' Law concerns the relationship between temperature, volume and pressure. It states that 'if the pressure remains constant, the volume of a given amount of gas is directly proportional to the absolute temperature'.

CIRIA: Construction Industry Research and Information Association (UK).

CIRSS: Comitato Italiano Ricerche Studi Subacquei (Italy).

Closed circuit: A breathing system within which the gas is re-circulated so that all the oxygen is used metabolically by the diver, and the exhaled carbon dioxide is absorbed in a chemical filter.

CMAS: Confédération Mondiale des Activités Subaquatiques (World Underwater Federation).

CNR: Consiglio Nazionale delle Ricerche (Italy).

CO_2: Carbon dioxide.

CPR: Cardio-Pulmonary Resuscitation.

Dalton's Law: Dalton's Law concerns the composition of air at various pressures. It states that 'the total pressure exerted by a mixture of gases is the sum of the pressures that would be exerted by each of the gases if it alone occupied the total volume'. The total pressure is the sum of the partial pressures of the gases present and as the overall pressure increases, so the partial pressure of the constituent gases increases.

DCB: Diving Control Board.

DCIEM: Defence and Civil Institute of Environmental Medicine (Canada).

DCS: Decompression Sickness.

DF: Direct feed. An intermediate pressure air hose with diver control for feeding breathing air from the main air bottle to ABLJ, for dry suit inflation, or other purposes.

DPV: Diver Propulsion Vehicle.

EAR: Expired Air Resuscitation.

EEZ: Exclusive Economic Zone.

EMT: Emergency Medical Technician

f.s.w.: Feet of sea water.

Graham's Law: Graham's Law concerns the rate at which different gases diffuse in a fluid. It states that 'the rate of diffusion of a gas, in relation to another, is inversely proportional to the square roots of the densities (or molecular weights).

H_2: Hydrogen gas.

H_2O: Water.

He: Helium.

Heliox: A breathing gas consisting of a mixture of helium and oxygen.

Henry's Law: Henry's Law relates to gas absorption in fluids. It states that 'the amount of gas that will dissolve in a liquid at a given temperature is directly proportional to the partial pressure of that gas over the liquid'. At increased pressures, increased volumes of gas can dissolve in liquid (e.g. blood).

Hg: Mercury.

HP: High Pressure.

Life Jacket: Legally, a life-jacket must be certified as able to support a person safely on the surface of the water with their face above water.

NAUI: National Association of Underwater Instructors (USA).

NERC: Natural Environment Research Council (UK).

Ni: Nickel.

Nitrox: A breathing gas consisting of a mixture of nitrogen and oxygen with a compostion in proportions different from that of air.

NOAA: National Oceanic and Atmospheric Administration (USA).

NSS: National Speleological Society (USA).

O_2: Oxygen.

Octopus rig: A breathing regulator with two (or more) hoses leading to second stage valves and mouthpieces, so that two (or more) divers can breathe at the same time from the same cylinder. An emergency breathing system.

OSHA: Occupational Safety and Health Administration (USA).

Pascal's Principal: Pressure applied to the surface of a fluid is transmitted to all parts of the fluid equally and undiminished.

RCV: Remote Controlled Vehicle.

RNLI: Royal National Lifeboat Institution.

RNPL: Royal Naval Physiological Laboratory.

ROV: Remotely Operated Vehicle.

SCOR: Scientific Committee on Oceanic Research (of International Council of Scientific Unions).

SCUBA: The word originated as an acronym for Self Contained Underwater Breathing Apparatus or S.C.U.B.A. Technically it could be used to include any breathing gas or breathing gas delivery system, provided that the diver was carrying the gas supply, without a surface supply. By universal acceptance the term scuba is used to describe a self-contained breathing set which contains compressed air and supplies through a demand valve. The word is used in that sense throughout the Code unless it is qualified by a second term. Thus, it is possible to say 'oxygen scuba', or 'nitrox scuba', to mean a self-contained breathing system providing a gas other than air, with the gas delivery method undefined.

SLJ: Surface Life-Jacket. A life-jacket commonly worn while snorkeling that has mouth and small emergency CO_2 gas cylinder inflation.

Stab Jacket: Stablizer jacket. An integral bouyancy system attached to the diver's back-pack or worn separately and usually inflated by direct feed. The manufacturer's instructions with these systems usually state that they cannot be treated legally as life-jackets and they should not be used for that purpose.

Surface Supply: A breathing system in which the gas is supplied through a hose from the surface at a higher pressure than the water pressure at the depth of the diver, and the pressure is reduced through a demand valve.

Tri-mix: A breathing gas consisting of oxygen and two inert gases, usually helium and nitrogen.

UASR: Underwater Association for Scientific Research (UK).

UBMS: Undersea Biomedical Society (USA).

UNCLOS: United Nations Convention on the Law of the Sea.

Unesco: United Nations Educational, Scientific and Cultural Organization.

USN: United States Navy.